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Bayonne as an Industrial Centre.

At the coming convention of the American Electrochemical Society one whole day—Friday, Oct. 29—will be devoted to an excursion to the city of Bayonne, N. J. From an engineering point of view, Bayonne is a most interesting “melting pot,” to borrow Mr. Zangwill’s phrase. In the Constable Hook section there are the big oil refineries, borax works, nickel works, and sulphuric acid works, with an interesting new briquetting plant. In the long string of works in the Newark Bay section, the manufacture comprises such varied products as boilers, submarine cables, electric launches, motors, oxy-acetylene welding apparatus, sulphur refining, extraction of fixed oils, manufacture of essential oils, etc. A goodly number of these works will open their doors to the Society, and the excursion should prove exceedingly interesting and instructive.

Electrode Losses and Furnace Efficiency.

Mr. Carl Hering’s interesting article in this issue will undoubtedly take an important and permanent place in the literature on the theory of electric furnaces. It brings the theoretical side of the laws of electrode losses into fairly satisfactory shape under the simplifying assumptions that the condition of operation is stationary (the temperature at any point remaining constant in time) and that no heat is given off from the electrode to the surrounding walls. Under these conditions it is always true that the heat passing from the furnace interior into the electrode can be written $H - \frac{1}{2} \bar{i}r$; and the heat passing from the outer end of the electrode into the cooling water $H + \frac{1}{2} \bar{i}r$. This is evident because the difference between these two quantities of heat must be just the total Joulean heat $\bar{i}r$ generated in the electrode. It is also easy to argue that H must be the heat which would flow from the hot inside to the cold outside if there was no electric current passing. We have thus a simple superposition of two phenomena; firstly, simple heat conduction H (as though there was no current flowing) and secondly, generation of heat from electrical energy within the electrode, this heat tending impartially to flow one half to the outside and one half to the inside (as though there was no heat conduction otherwise). This seems all very simple, but the difficulty of the whole problem is due to the fact that the temperature and with it the electric and thermal conductivities of the electrode material change from point to point. What “mean” thermal conductivity shall we choose in the calculation of the simple heat conduction H as sketched above? Nor does Mr. Hering’s analysis help over this difficulty. His fundamental differential equation on page 443 is strictly correct. But in integrating it—equations (3) and (4)—he silently assumes w and k to be constant. Nevertheless the results, as found by Mr. Hering, represent a fair first approximation to the truth—undoubtedly the best we have at present.

The second part of Mr. Hering’s article shows how, on the

basis of this theory, it is always possible to find a "best" value of the ratio of cross-section to length of electrode; this best value corresponding to minimum electrode loss. Theoretically it must be said that minimum electrode loss is not identical with maximum furnace efficiency; the best value of the ratio for maximum efficiency is represented by a more unwieldy formula than Mr. Hering's very simple formula (22) for minimum electrode losses. But for large furnace capacities both formulas become the same. If arguing further on this point we might drive a nice theoretical point a little too far, in view of the difficulty of practically applying even such a simple and handy formula as Mr. Hering's (22). The difficulty is that there is very few exact data published on the fundamental constants of heat and electric conductivities at high temperatures. On the basis of those that are available, Mr. Hering makes a very courageous and interesting calculation for graphite and carbon. However, as this whole subject will be discussed in several papers at the coming convention of the American Electrochemical Society, we defer further comment until that time, and meanwhile recommend Mr. Hering's paper to the careful attention of everybody interested in electric-furnace design.

Uniform Nomenclature of Iron and Steel.

The report of Committee 24 at the recent Congress at Copenhagen (described at length elsewhere) recalls similar attempts in the same direction, dating back to the first Commission's report at the Centennial Exhibition, in 1876. That first Committee was truly representative and international in character, and its report was the result of much careful deliberation, but it fell flat, and scarcely one of its recommendations has passed into commercial or scientific use. A similar fate awaits the 1909 report, which is less carefully considered and more faulty than the first. The simple fact is that all such reports, elaborated along the lines adopted, are doomed to failure because conceived upon wrong principles. As far as their practical influence extends or will extend, such as have been made and such as will be made upon a similar plan of procedure, are scarcely worth the paper they are printed upon, certainly not worth the time and trouble which are expended upon them. The false principle involved is that of allowing the iron and steel industry to bring forth new commercial products and to name them and sell them as "such and such" according to the most illogical or nonsensical exigencies of commerce, and then some years later stepping in to reform the errors when it has become forever too late. Commercial designations once fixed, no matter how unsuitable or unscientific, are next to impossible of correction. The committees studying this question of a uniform and consistent nomenclature have been limited in their activity either to describing a confusion which they were powerless to straighten out, or to proposing reforms which they were incapable of enforcing.

The question is then to be considered, as to whether some reform, some plan of uniform nomenclature, some principle of procedure, is at all feasible. We are sure that there is a possibility of improving upon the present status, and of doing it with reasonable satisfaction to all concerned. But the reform must proceed upon different principles from those of the aforementioned committees or commissions. First: The fact must

be recognized that names and designations in commercial use are practically fixtures, and attempts should be made to define them or to substitute others only where the name is so utterly false and misleading as to lend itself to misrepresentation and fraud. The commercial world will then recognize a vital reason for the proposed reform and will be likely to accept it. The proposed nomenclatures have been fundamentally faulty in that they recommended changes upon other grounds than the above-described necessity, and the commercial world has simply ignored the recommendations. Second: Having made a foundation by accepting the bulk of the existing commercial nomenclature, and having proposed revisions of only such as commerce will recognize the absolute necessity of changing, the next and most promising principle of action is to provide the machinery by which new commercial products can receive proper names as soon as they appear. To put the matter in other words, it means to establish a bureau of registration of births, with the proper officials to provide a suitable name and to give the youngster official and orthodox baptism. Once such machinery is put into active operation, the hit-or-miss naming of new products, the nicknaming instead of regular baptism, may become a thing of the past, and a systematic uniform nomenclature gradually evolve in the place of the present chaos. It is a fact that many new and valuable commercial varieties of iron and steel have been on the market for years before any authoritative commission recommended names for them (we may mention mild steel and electric steel as examples), and here is the weak spot of the whole question.

* * *

To put an end to the present unsatisfactory conditions, and to provide the machinery for building up a proper nomenclature upon sound principles of action, we make the following proposition, which we recommend to the parties most concerned: Let the American Institute of Mining Engineers, the Iron and Steel Institute of Great Britain, Verein Deutscher Eisenhüttenleute, Jern Kontoret of Sweden, Comité des Forges de France and International Association for Testing Materials each appoint one member of an international committee, each member being appointed for one year, so as to provide against too great fixity in the personnel of the committee, and such committee to be permanent. Its functions will be to recommend such changes in existing nomenclature as it deems absolutely necessary for guarding against commercial dishonesty, but further, and, much more importantly, to recommend suitable and correct names for new commercial products as soon as they appear. Its recommendations would be recognized as binding upon the concurring societies, and could undoubtedly soon gain such weight as to obtain government sanction and adoption in all countries where the above societies possess influence—i.e., in all civilized countries. The above proposal is not destructive; it is intended to be reformatory to only a minor and absolutely necessary extent; its chief function is to be preventative of future confusion and to be eminently constructive in its application. One society must take the initiative. Will not the American Institute of Mining Engineers appoint its member of this commission, and invite severally the other five to appoint theirs? Let us apply the principles of preventive medicine to the matter, and not be forever dosing the sick man whom we have allowed to get sick, or making post mortems.

Raw Materials and Finished Products in the Iron and Steel Industry.

In its recovery from the recent depression the iron and steel trade finds itself at about the same chronological stage as was reached early in 1905 after the 1903-4 depression. The existing capacity is about equally well employed, while in a general way the recovery in the average level has proceeded by about the same amount as at the earlier time. There have been many points of similarity between the depressions of 1903-4 and 1908-9. As to time, they were of about equal duration, while in each case there was a partial maintenance of finished steel prices, with a wide-open pig-iron market, followed by a break in steel prices, followed quickly by a recovery in which pig iron joined. The points of dissimilarity were relatively minor. In 1903 pig-iron production began to decline in midsummer, and declined gradually for a few months and then rapidly. In 1907 maximum production was reached in October, and the decrease in production in less than three months exceeded 50 per cent. In 1903 pig-iron prices declined steadily through the year; in 1907 the decline began in midsummer, so that in each case prices began to decline a few months before production began to decline. In finished products some prices broke late in 1903, while a few did not break until September, 1904. In the later period prices were more uniformly held, there being no serious breaks until the period Feb. 18 to May 1. In the earlier period the recovery in pig-iron prices started in July, 1904, and the recovery in finished products started in October. In the later period prices of both pig iron and finished products began to recover in May.

The recovery accomplished in 1904 and the early part of 1905, the iron and steel trade was continuously prosperous until late in 1907. The trade has again recovered, but for how long its prosperity will continue is for the future to decide. From the above and other comparisons that might be made, it seems fair to take the early part of March, 1905, as the time in the previous recovery corresponding chronologically with the present in this recovery. Prices compare as follows:

	March 1, 1905.	Oct. 1, 1909.
Mesabi Bessemer ore	\$3.50	\$4.25
Mesabi non-Bessemer ore	3.00	3.50
Connellsville furnace coke	2.25	2.75
Bessemer pig iron, valley	15.50	18.00
No. 2 foundry iron, Birmingham....	13.50	14.50
Steel billets	23.50	26.00
Rails	28.00	28.00
Plates	1.60	1.50
Shapes	1.60	1.50
Steel bars	1.50	1.40
Sheets, 28 gage	2.25	2.20
Plain wire	1.65	1.60

Rails stand at the same price at each date. All cruder materials are at higher prices now than on March 1, 1905, while finished products are at a lower level all along the line. The table enumerates the principal finished steel products. Other products would presumably show the same relation.

In the case of Lake Superior ore the difference is really greater than appears in the comparison. For March 1, 1905, we give prices for the season 1905, representing an advance over the season of 1904 of 75 cents on Bessemer and 65 cents on non-Bessemer ores, whereas for the present date we give

prices for the season just ending, when there are clear prospects that for the season of 1910 there will be an advance of 50 cents. While the table shows an advance of 50 to 75 cents, the spirit of the situation represents more than \$1. Connellsville coke shows an advance of 50 cents, Bessemer pig iron an advance of \$2.50 and Southern pig iron an advance of \$1. What is the rationale of this departure in the relation between crude and finished products? Some may answer that finished steel prices broke violently in the fore part of the year, after a long period of price maintenance, while coke and pig-iron prices had been subject to market adjustment all through 1908, and that it is therefore natural that finished steel prices should be slower in recovery. We do not concur. Shorn of the by-play, the recent movement to maintain prices was not greatly different from that in the earlier period. Granting, however, that the break was more violent, why should not the rebound be sharper? Why should coke and pig iron, which had comfortably settled to bottom more than once, advance so rapidly? Others will probably answer that this is a period of readjustment, and comparisons should not be carried too far. We are not carrying the comparison far; it requires no hair splitting to develop from the table that crude and finished products are in widely distinct classes as to the price movement. It is too much to charge to accident.

* * *

A scrutiny of conditions in the branches of the industry involved readily discloses reasons for the difference. Lake Superior iron ores have come to be tightly held and the owners are in position to charge prices which present conditions justify. Connellsville coking coal lands are not so tightly held; ownership is fairly well distributed, and severe competition has appeared on occasion, but at the present rate of exhaustion the life of the region promises to be 30 years or less, while many of the operations have but a few years before them. Pig iron is naturally higher when its direct raw materials are higher; Southern iron, while produced in a distinct region, is marketed largely where Northern raw material conditions dictate prices. With lower prices for finished products, the industry is paying greater tribute to the raw material. Lake Superior ore and Connellsville coke are the best materials which have been found in the United States, but the relative prices paid for them have been getting higher and higher. A spirit of restlessness has appeared in recent years, and by-product coke and Cuban ores, by way of instance, have been sought. This spirit of restlessness is destined to increase. In point of tonnage it has produced comparatively little of result thus far, but the expansion has really been hampered by the great expansion in demand for finished product ready for use. There has been little time afforded for investigation and exploitation of minerals, and the introduction of new processes or modifications for the use of new minerals. It has been necessary to double pig-iron production every 10 years, and the growth in tonnage, with its wonderful achievements in the handling of materials, has far exceeded the improvement in metallurgical methods. There is good reason to believe that conditions will be different in the next decade or two, and that while tonnage will continue to increase and the mechanics of manipulation will continue to improve, more important forward steps will be taken in metallurgical processes for the adaptation of less convenient raw materials than Lake Superior ore and Connellsville coke.

Fifth International Congress for Testing Materials.

(From Our Special Correspondent.)

Copenhagen was the place chosen for this fifth congress, and a very happy choice it proved to be. Somewhat out of the beaten tracks, the capital of Denmark was proud to act the host, and the Congress would certainly have completely monopolized the attention of the Danes, had not Dr. Cook, of North Pole fame, arrived almost simultaneously with the Congress and shared public attention with it.

At the opening ceremonies in the Aula of the University, at 10 a. m., Sept. 7, the Congress was honored by the attendance of the King and Queen of Denmark, while the Crown-Prince was present as honorary president of the Congress. Some 30 Governments were officially represented, and the beautifully decorated hall, full-dress assemblage, picturesque costumes and uniforms of foreign delegates and military, made a most impressive *ensemble*. President Foss opened the exercises, the Crown Prince responded, and Mr. Paul Larsen, of Copenhagen, then read, most inopportunistly, a long technical paper on the development of the Danish cement industry—a communication which should have been presented at one of the section meetings and there read *by title* only.

The business of the Congress was conducted in three sections: (A) Metals and metallography; (B) Cement and concrete; (C) Various materials. These sections met on the mornings and early afternoons of Sept. 8, 9 and 10, while the rest of the afternoons were given over to excursions and the evenings to entertainments; for instance, excursions to the Royal Porcelain Works, Polytechnic Academy, State Testing Laboratory, etc., and later opera at the Royal Theatre, reception by the Mayor and City Council in the Town Hall—a most brilliant affair.

Coming to the work of the Congress, Section A (metals) was most comfortably and even luxuriously installed in the council chamber of the City Hall. Sections B and C had to content themselves with much less comfortable and restricted quarters in the basement of the same building; it may be remarked with truth and candor that these two sections held their meetings under difficulties. The papers of Section A were divided under the headings: Metallography, hardness tests, impact tests, alternating stress tests, tests of cast iron, influence of temperature on mechanical properties of metals, magnetic and electric properties of metals, internal strains, reports of committees. Section B divided its communications into: Reinforced concrete, methods of testing, action of sea water on cement, weathering resistance of building stones, various reports. Section C had communications upon: Oils, rubber, wood, protective coatings for metallic structures, paper, general regulations for international tests.

Among the numerous papers presented there were not many which attracted great attention. Your correspondent limited his attention to the proceedings of Section A, and can therefore report personally only thereupon.

The report of Professor Heyn upon the progress of metallography from 1906 to 1909 was severely criticised by English, French, and Americans, as very incompletely representing the progress made in their respective countries, and protest was made against printing it in the proceedings of the congress without many necessary additions.

The report of the Committee for the Establishment of International Specifications for Iron and Steel, presented by Dr. Rieppel, was vigorously attacked by Leon Guillet, of Paris, and as vigorously defended by Professor Heyn, of Charlottenburg. It looked for a time as if the matter would become a Franco-German squabble, but outsiders gradually took part in the discussion and Professors Heyn and Guillet finally retired to adjust their differences, which was happily accomplished. Professor Webster, of the University of Pennsylvania, took part vigorously on behalf of the American members, and the report was finally laid on the table and the committee requested to continue its labors.

Somewhat similarly, the report of the committee on the uniform nomenclature of iron and steel was attacked to such an extent that it was finally referred back to the committee with instructions to consult, and if possible agree, with national scientific societies before handing in a revised report to the next congress. Prof. H. M. Howe, chairman, was not present to defend the report, which was vigorously criticised. Messrs. Pourcel and Greiner presented a printed protest against the proposed definition of "steel," others criticised the proposed metallographic terms and definitions. Prof. J. W. Richards, of Lehigh University, criticised the report for some erroneous definitions, some inexcusable omissions, and finally as being based on a faulty principle which could never lead to any practical results or acceptable conclusions. The report was referred back to the committee for improvement and revision.

Abstracts of some papers and reports will be found in the Synopsis in this issue. Before closing, we would remark on the futility of attempting at an International Congress to put the papers and discussions into two or three languages. As far as discussions are concerned, proper statement in either French, German or English, in the speaker's own tongue, should be and is, in reality, sufficient; the attempt to put what is thus said into another of these three languages is in 9 cases out of 10 a flat failure and a sheer waste of valuable time. The printing, in a hurry, of a paper in three languages is also a disappointment and a failure. The translations are usually miserably done, by incompetent persons, and the result is confusion and a waste of good ink and paper. One example will illustrate this point sufficiently well: A small electric furnace was described, the outer case of which was a section of terra-cotta drain or sewer pipe. The translator (*sic*) spoke of this section of pipe, throughout the description, as a "cesspool." We beg pardon of our readers for such a coarse reference, but the disgust provoked is paralleled by our impatience at the inaninity of attempting translations under such circumstances. We would most strongly recommend to the authorities of future similar Congresses, that the translation be always carefully read in manuscript or proof by a competent person who reads it as his mother tongue. Only in that way can false syntax, awkward expressions and mistranslations be satisfactorily avoided.

The Iron and Steel Market.

Instead of moderating its pace as prices have been reached more nearly approaching what the experience of recent years would indicate as normal, the iron and steel market has advanced more rapidly. In the past month the trade has accepted the conclusion that a genuine bull movement is on and speculation is rife as to how long the improvement will last. Conditions appear to be such as to promise a continuance of rising, or at least firm, prices for six months at least, with increasing tonnage. It has sometimes been said that the iron trade can never look more than six or nine months ahead, so that prospects are really as favorable as could be expected at any time.

Specifications on old contracts for finished steel products continue at an entirely satisfactory rate, while the volume of new buying has been increasing, the combined result being to book mills farther and farther ahead.

Prices of some finished steel products advanced during September, steel bars \$1 a ton to \$1.40, Pittsburgh, and plates and shapes \$2 a ton to \$2.50, Pittsburgh. Sheets have shown a firmer tone, mills being less disposed to contract far ahead at current prices. Premiums on tin plate for early delivery almost disappeared, but that was due to the close of the period calling for the heaviest deliveries, prospects for a general advance for next year's deliveries increasing. Wire products have been uninteresting, being practically out of season. Steel pipe did not experience the expected advance, and it is now rather late in the season to expect one. Wrought-iron pipe, however, was advanced one point, or \$2 a net ton, to a basis six points above

steel pipe. Railroad spikes have strengthened, to \$1.70, and an advance is expected for next year's delivery. Rail buying for 1910 delivery has been moderately large, and output promises to be larger than in the current year, although possibly not reaching the record tonnage made in 1906.

An interesting and rather unexpected feature in this general upward movement is that the cruder materials have advanced to a higher level, proportionate to finished steel products, than was the case in the recovery, in 1904-5, from the depression of 1903. With finished steel products at a materially lower average level than prevailed during the first half of 1905, pig iron and coke are at a materially higher level than in that period. Lake Superior ore, of course, has not changed in price, being at the 50-cent reduction made for the season of 1908, but is higher than in 1905 or even in 1906, and it seems to be accepted that a 50-cent advance will be made for next season.

The three years 1905-6-7 formed a period of sustained demand for steel products, with prices slightly advancing. As noted, even the prices early in 1905 were higher than those now ruling, yet it was not until August, 1906, that Bessemer pig iron reached the level now prevailing, the average price in 1905 being \$2.50 below to-day's market. Connellsville coke makes a similar showing, and, as noted, Lake Superior ore does likewise.

Pig Iron.

Bessemer pig iron has led the market in the Central West, with sales to this writing in excess of 125,000 tons and a few closing days of the month still to be heard from, while the price advanced from \$16.75, valley, to \$18. The chief buyers were the Jones & Laughlin Steel Company, Republic Iron & Steel Company, Lackawanna Steel Company and Youngstown Sheet & Tube Company. Having a large production of their own, these interests only buy when their steel plants are running very full. Deliveries in all these cases were for this year, but some minor purchases have been made for next year. The movement in basic iron has been comparatively light, and it can be quoted nominally at a dollar under Bessemer. Foundry iron in the valleys advanced under the lead of Bessemer to \$16.50, valley, for this year, and \$17 to \$17.50 for first quarter. The Southern market has been advancing steadily and late in September reached \$14.50, Birmingham, with predictions freely made that \$16 would be reached by early in the new year.

Unfinished Steel.

Most of the mills have disappeared as sellers of billets, having their steel output fully taken up by their own finishing departments. All lines of unfinished steel have advanced from \$1 to \$2 since last report, and are hard to get at the advanced prices. We quote, f.o.b. mill, Pittsburgh district: Bessemer billets, \$25.50 to \$26; open-hearth billets, \$26 to \$26.50; sheet bars, \$26.50 to \$27; Bessemer rods, \$31.50; open-hearth rods, \$32. The Carnegie Steel Company has started its sheet bar mill at Columbus, Ohio, its smallest Bessemer operation, and now has practically all its Bessemer and open-hearth capacity in operation.

Finished Materials.

Bars, plates and shapes, as already noted, have advanced since last report. While mills are sold up for from 4 to 10 weeks ahead on nearly all classes of material, the tendency is to ask higher prices the farther forward the delivery. In some lines business will not be done for next year, while in general engagements will not be made beyond the first quarter. An exception, of course, is rails. Total bookings for 1910 delivery now exceed 300,000 tons. The market is quotable as follows, f.o.b. Pittsburgh:

Steel bars, \$1.40, base.

Iron bars, \$1.50 to \$1.55, base.

Plates, \$1.50.

Shapes, \$1.50.

Standard rails, \$28 for Bessemer and \$30 for open-hearth, f.o.b. mill; light rails, 25 lb. to 45 lb., \$28.

Sheets, 28 gage, black, \$2.20; galvanized, \$3.25; corrugated roofing, \$1.55 per square for painted and \$2.80 for galvanized.

Merchant steel pipe, 3/4 in. to 6 in. inclusive, extreme price 81 and 5 off list; wrought-iron pipe, 75 and 5 off list.

Plain wire, \$1.60; wire nails, \$1.80, base; painted barb wire, \$1.80; galvanized barb wire, \$2.10.

A Court Decision on the Fume Question.

In the injunction proceedings of Phoebe Gore and others against the Clarksburg Zinc Company (which treats "salamoniatic skimmings"), an opinion has been rendered by Judge Charles W. Lynch, in which he declines to abate the company's plant as a public nuisance. From the full opinion of Judge Lynch, as printed in the *Daily Telegram*, of Clarksburg, W. Va., we quote the following:

It is pointed out that there is an immense mass of directly contradictory testimony. But "one fact, at least, is proven, in effect practically conceded, viz., that at times, either prior to the institution of this suit, or afterward and before the injunction was awarded, the resultant effect from the plant's operation was injurious to both animal and vegetable life, and especially the latter, for within a reasonably brief period trees and plants within the immediate reach of the noxious gases or vapors, and apparently healthful, were about that time denuded to some extent of their foliage without apparent cause other than reasonably chargeable to the operation of the factory.

"The defendants seek to excuse this result by evidence to the effect that the part of the plant generally known as the roaster was then but recently installed and had not been properly reduced to a good working basis. In other words, that it was in the experimental stage."

The defendants now claim that by changing the roasting plant the fumes have been entirely changed and are no longer detrimental to health. This the complainants deny, but their testimony is in the main from the plaintiffs themselves, while the defendant company produced expert witnesses. "The court must of necessity attach more weight and credit to the testimony of expert witnesses, that is, witnesses who are specially informed and whose special study has been to know accurately the nature and character of the gases and vapors produced and discharged in the operation of the factory, than to the testimony of those who do not pretend to know the character or nature of the gases or vapors so produced."

The final conclusion of Judge Lynch is as follows:

"The defendants are engaged in a useful and lawful business. It is not a nuisance per se. That, however, does not confer upon them the right to unnecessarily harass the plaintiffs in the enjoyment of their homes. Both must be protected so long as they can reasonably exist together. As Judge Holt has said, courts must 'apply the common-sense doctrine that the parties must give and take, live and let live.'"

"There must, therefore, be a decree refusing to abate the Clarksburg Zinc Works as a nuisance, but at the same time restraining and enjoining the defendants and each of them from the use of any material in the distilling or roasting furnaces the reduction of which will produce into the air any gases or vapor causing physical injury or damage to the person or property of the plaintiffs."

Electric Iron and Steel Industry in Canada, and in Sweden and Norway.

We are glad to hear from Mr. LOUIS SIMPSON that negotiations for an electric iron-ore reduction and steel plant in Canada are well advanced. The first plant is to have a capacity of 5000 hp.

From a pleasant interview which we had with Mr. ASSAR GRÖNWALL (one of the three inventors of the electric iron reduction furnace recently investigated and officially reported on

by Dr. E. Haanel, Director of Mines, Ottawa, Canada), we learn that considerable progress has recently been made in Sweden and Norway in this field. Mr. Grönwall was only a week in the country and was called back to Europe to meet a delegation from the largest iron and steel works in Russia.

From Mr. Grönwall we learn that the iron-ore reduction furnace described and illustrated in Dr. Haanel's paper in our June issue has been working continuously for three months, until July 3, when the general strike in Sweden caused a stoppage of operation. One point which Mr. Grönwall emphasizes is that they have had no trouble whatever with their electrodes. In their three-phase furnace two of their electrodes were sometimes moved for demonstration purposes, but one electrode of the three was purposely not moved and remained in satisfactory condition for six weeks. It was then adjusted and could stand another six weeks.

The electrodes are immersed in the charge, but do not dip into the molten iron at the bottom of the furnace. In tapping the furnace the ammeter does not move, which proves that practically no current is passing through the molten iron at the bottom.

One point strongly emphasized by Mr. Grönwall is that the combination of an electric reduction furnace with electric steel furnaces is important because it is easy to make in the former a pig iron of low carbon content, say, 1° C. If the molten pig iron is transferred directly to the electric refining furnace, the time necessary for getting the desired quality of steel is much less than with present electric steel refining practice. He states that this practical elimination of the carbon in the reduction furnace is very important, since the comparatively long time required in present electric steel refining practice for reducing the carbon content is completely saved. From the three months' running of their reduction furnace they conclude that there can be no doubt of its working efficiently on a large commercial scale.

In this connection it is interesting to note the official report of Dr. EUGENE HAANEL to the Canadian Government on his visit to Sweden, where he investigated the electric reduction furnace above mentioned at the Aktiebolaget Electrometall, at Donnarfvet, Sweden. The report proper gives details of this investigation by Dr. Haanel. Since the chief results were already given by Dr. Haanel in his American Electrochemical Society paper at Niagara Falls, published in our June issue, we will only quote the official final statements in the report:

"The trial run was intended to elucidate the following points:

"(1) Whether undisturbed and uniform working without troublesome regulation of the electrodes could be obtained.

"(2) Whether great variations in the consumption of energy would occur.

"(3) Whether the free spaces within the melting chamber would be maintained with a shaft considerably higher than in the furnaces of earlier design and construction.

"(4) Whether the contraction of the shaft would prevent the charge from sinking uniformly, or cause hanging.

"(5) The durability of the arched roof, and the possibility of cooling it by means of the circulating gas.

"The following is a summarized statement of practical deductions drawn from observations made during the trial run, having regard to the objective points specified above:

"(a) It was observed that the furnace operated uniformly and without trouble of any kind, and that the electrodes required absolutely no regulation, in one case, for five consecutive days. In any case, the only regulation required is that corresponding to the consumption of the electrodes, and is necessary only once a day, and sometimes not for much longer periods. On account of this, expensive regulations can be dispensed with.

"(b) During the short trial, even though the furnace did not approach its normal working condition until toward the end, it was observed that the consumption of energy was remarkably

uniform. This can readily be seen from an inspection of the readings of the different instruments.

"(c) Free spaces were maintained between the linings of the roof and the walls, and the electrodes and the charge at the openings where the electrodes enter the melting chamber.

"(d) It was found that the charge did not jam in the lower contracted neck of the shaft, as had been feared, but moved with regularity into the melting chamber.

"(e) Although the gases generated by the reduction of the ore were not circulated through the cooling tuyeres until near the end of the trial run, it was demonstrated that the lining of the roof of the melting chamber was effectively cooled by this means."

Since the sectional drawing of the furnace was published in

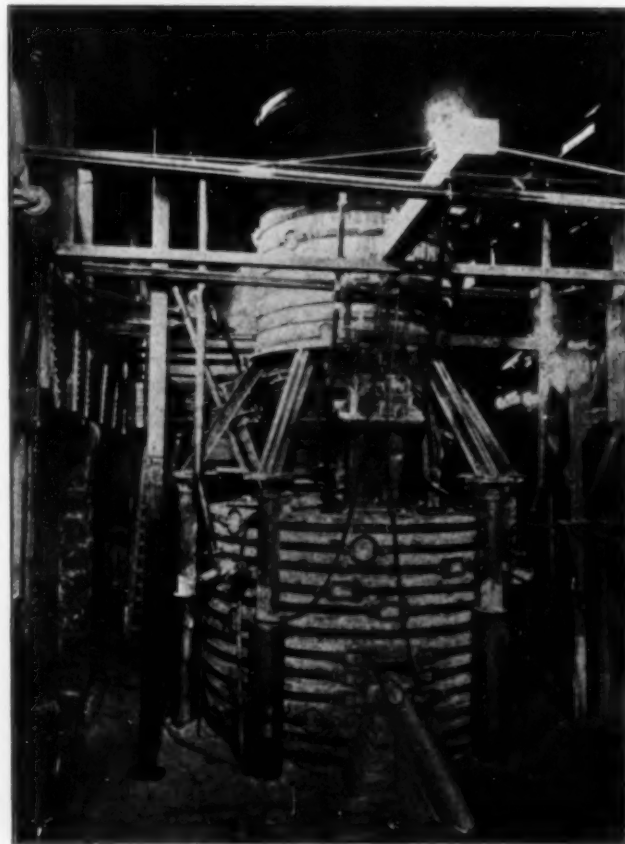


FIG. 1.—ELECTRIC REDUCTION FURNACE FOR IRON ORE.

our June issue, we reproduce herewith only an outside view of this electric shaft furnace (Fig. 1).

Dr. Haanel's report then contains a comparison, by Professor von Odelstierna, of Stockholm, of the cost of production of pig iron in a charcoal blast furnace and an electric shaft furnace based on conditions in Sweden. This comparison is as follows:

"If we take as a basis for our comparative study an ordinary charcoal blast furnace and the electric shaft furnace erected at Donnarfvet, and suppose the iron ore used in these furnaces to contain 60 per cent metallic iron, and the charcoal 83 per cent carbon, then it should be possible to make a reliable comparison. It should be pointed out, however, that in this comparison no account is taken of the fact that the gases produced in the electric shaft furnace contain a higher percentage of CO—probably 60 per cent more—than the ordinary blast-furnace gases.

"In regard to the labor charges and general expenses, I make the supposition that these charges are the same for both the electric shaft furnace and the charcoal blast furnace, if the contrasted furnaces are of such capacity as to produce the

same quantity of pig iron per year. A charcoal blast furnace of medium capacity produces in Sweden about 8000 to 10,000 short tons of pig iron per annum—a quantity which, I believe, can also be produced in a properly constructed electric shaft furnace of the type of Atkiebolaget Electrometall.

"Cost of pig iron per short ton, in dollars:

Charcoal Blast Furnace.		Electric Shaft Furnace.	
Charcoal, 0.95 ton, at \$8 per ton	\$7.60	0.27 ton charcoal	\$2.16
Labor	1.00	0.3 E. H. P. year at \$12	3.60
Repairs and general expenses. 1.50		Electrodes, 10 lbs., at 3c per lb. ....	.30
		Repairs and general expenses. 1.50	
Total	\$10.10	Total	\$8.56

"In this calculation the price of ore and limestone, and the royalty are not given, as the former varies with the locality and the character of the ore, and the latter has not yet been determined.

"From this calculation it is apparent that in Sweden, under the above-mentioned circumstances, a saving of \$1.55 should be effected in the production of pig iron by the electrothermic process."

It may be interesting to note in this connection that according to reliable reports which have reached us, quite satisfactory progress is also being made with electric iron-ore reduction in the Noble plant in California. (See our June issue.)

Electric Steel Furnace

In the second part of Dr. Haanel's report an interesting description is given of the electric steel furnace of Assar Grönwall, Axel Lindblad and Otto Stalhane, the three inventors of the iron-ore reduction furnace referred to above.

"Either a two-phase or three-phase current can be used with this furnace, which has but two adjustable electrodes; the bottom of the hearth—composed of magnesite, intermixed with a small amount of graphite—forming the third.

"By the special distribution of the electrodes the bath is caused to rotate in a vertical plane, thus continually bringing new material in contact with the slag for purification. The time required for refining is by this means considerably shortened.

"If the current to be supplied is two-phase, an ordinary two-phase transformer can be used with the furnace; but if the supply is three-phase, two single-phase transformers with Scott's connection can be used."

The two-phase current is supplied to the furnace in such a manner "that the terminals of one pole of the two phases are each electrically connected with one of the two adjustable electrodes of the furnace, while the terminals of the other poles of the two phases are electrically connected with the lining of the furnace." The currents from the two electrodes thus pass in form of two arcs into the bath; the current in the bath is $\sqrt{2}$ times the current in each phase. The current leaves the furnace through the bottom lining.

A vertical section of the furnace and a horizontal section (at the top) are shown in Fig. 2.

"The furnace* is built on iron plates 10, which also serve as conductors for the resultant current of the phases; for this purpose they are connected with the conductors 14. The walls are constructed in the usual manner. When soft iron or steel is to be produced, the lining is made of magnesite, dolomite or

quartz. Since these substances are conductors of the second class, and consequently must be at rather a high temperature in order to conduct electricity well, a layer 11 of graphite, for example, would be rammed in on the plates 10. This material, when cold, is an excellent conductor of electricity and serves the purpose of conducting the current until the lining attains the proper temperature to become itself a conductor. Where the lining is composed of magnesite or dolomite, with tar, pitch or the like, as an adhesive, it is usually a sufficiently good conductor, on account of the carbon introduced in this manner, even when in a cold condition. Under these conditions the conducting layer 11 can then, if desired, be omitted. The two electrodes 12 are connected to the free ends of the phases. These electrodes penetrate into the cupula of the furnace and are adjustable. For the purpose of protecting the brickwork of the cupula the electrodes pass through water-

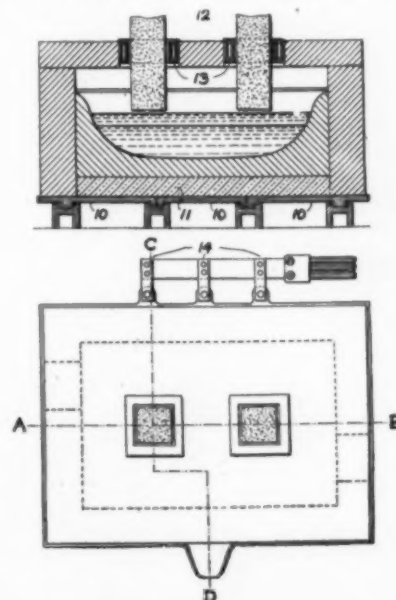


FIG. 2.—ELECTRIC STEEL FURNACE.

cooled stuffing boxes 13. The electrodes are so adjusted that there is formed between them and the bath or layer of slag floating thereon an arc of suitable length.

"With this furnace all processes occurring in the production of iron and steel, such as puddling, desulphurization, dephosphorization, etc., can be carried out."

* * *

In the third and fourth parts of Dr. Haanel's report some important accessories of electric iron and steel plants are discussed.

Part III deals with factories for making carbon electrodes, and contains essentially a description, by Mr. Jens Orten-Boving, of London, of a factory producing yearly 3000 tons of large-size carbon electrodes. This description is based on facts and operating results obtained from two large factories, constructed on similar lines. The first is that of Messrs. Höganas-Billesholm, Limited, of Sweden, who have a carbon factory of 2000 tons yearly output, making electrodes for carbide furnaces, steel smelting furnaces and aluminium works. The second plant is that of the British Aluminium Company, Limited, who have a factory, at Kinloch Leven, Scotland, producing yearly 6000 tons of electrodes for their own aluminium works.

A discussion is given of the raw materials used, the general arrangement of works, the coarse crushing plant, the fine crushing plant, tar heating, mixing of coal and tar, presses and pumping plant, and Menheim's gas kiln. Finally, an estimate is given of first cost and operating expenses.

*The above description is taken by Dr. Haanel from the Swedish patent specification of the inventors. It will be seen that, aside from the poly-phase connections, the furnace resembles the Girod type rather than the Heroult type, since it has an electric bottom connection. But it differs from the Girod type in the nature of the furnace bottom. As we understand from our conversation with Mr. Grönwall, the furnace bottom as they now use it, is essentially a "conductor of the second class." That means, when cold, it does not conduct. Just like the "pole plates" in the Roehling-Rodenhauser furnace, the bottom in the Grönwall-Lindblad-Stalhane furnace must be preheated in order to become a conductor. In the Roehling-Rodenhauser furnace this is done by the charge itself heated by induction. This permits a quick starting of the furnace, but it makes necessary a combination of an induction furnace with a pole-plate furnace. The Grönwall-Lindblad-Stalhane furnace avoids any complications in construction, but it requires quite some time for starting. This is no disadvantage, as it is intended for continuous operation only. When the furnace is to be started, coke is filled in, and by burning the coke the furnace bottom is brought to the required temperature to become a conductor. This may take a day, but when the furnace is then started, it can be used continuously.—Editor.

In the fourth chapter a review is given of modern methods of manufacturing charcoal for electric iron-ore reduction furnaces.

This full and well illustrated "Report on the Investigation of an Electric Shaft Furnace" at Domnarfvet, Sweden, may be obtained on application to Dr. Eugene Haanel, Director of Mines, Department of Mines of Canada, Ottawa, Canada.

Together with his well-known two former reports, this third report of Dr. Haanel forms a trilogy which may well be characterized by the statement made about the first report by an English technical contemporary: "It stands a monument of legitimate Government activity, directed with intelligence and achieving its goal."

New York Meeting of American Electrochemical Society.

The autumn meeting of the American Electrochemical Society will be held in New York City on Oct. 28, 29 and 30 (Thursday to Saturday of the last week in October).

While the program has not yet been definitely arranged, it is probable that sessions for the reading and discussion of papers will be held on Thursday afternoon and Saturday morning; perhaps also on Saturday afternoon.

The whole of Friday will probably be devoted to an excursion to the numerous and exceedingly interesting chemical and metallurgical plants in Bayonne City, the plants on Constable Hook to be visited in the morning, those on the Newark Bay side in the afternoon. On the evening of Friday a banquet will be held in New York City.

The local committees are making strenuous efforts for the entertainment of visitors, and especially of the ladies. The program of papers to be presented at the professional sessions is stated to be again very interesting. The hotel headquarters will be at the Hotel Cumberland, Broadway and Fifty-fourth Street.

American Institute of Chemical Engineers.

The annual meeting of the American Institute of Chemical Engineers will be held in Philadelphia from Dec. 8 to 10. Excursions to a number of centers of interesting chemical industries in the vicinity is being arranged for. The program of papers to be presented will be published later.

Coke, Gas, Tar, and Ammonia.

The manufacture of coke by processes that will permit the saving of the by-products gas, tar, and ammonia, and thus reduce to some extent the enormous wastefulness of the beehive ovens, is discussed by E. W. Parker in an advance chapter of "mineral resources of the United States, calendar year 1908," just issued by the United States Geological Survey.

During the last 15 years considerable progress has been made in the manufacture of coke in retort ovens, with the recovery of the by-products, but the future development of this branch of the industry depends largely on the ability of the operators to dispose of the by-products at remunerative prices. They come directly into competition with the products of gas-house retorts, and the situation thus created has developed a demand for information in respect to the total quantities produced and the values.

The quantity of coke produced at gas works and by-product coke ovens in 1908 was 6,253,125 short tons, a marked decrease from the figures of 1907 (8,093,144 tons), the business depression causing a heavy falling off in the demand. The value dropped from \$30,332,644 to \$21,507,045, a reduction of nearly \$9,000,000.

Gas showed a slight increase in value, the quantity sold being 53,561,811,000 cu. ft., valued at \$37,227,901, in 1908, as compared with 54,819,685,000 cu. ft., valued at \$36,462,304, in 1907.

Tar and ammonia decreased slightly, the figures being 101,261,829 gal. of tar, valued at \$2,537,118, in 1908, against 103,577,760 gal., valued at \$2,651,527, in 1907; 30,615,835 lb. of ammonia, valued at \$2,065,169, in 1908, against 37,560,858 lb., valued at \$2,601,057, in 1907; and 44,093,437 lb. of ammonium sulphate, valued at \$1,322,807, in 1908, against 48,882,237 lb., valued at \$1,525,472, in 1907.

The coal carbonized in this production amounted to 9,252,978 short tons, against 11,490,661 short tons in 1907. The increasing popularity of gas for cooking and heating purposes is shown by the fact that the proportion of the total production used for these purposes in 1908 was double that of 1902.

Mr. Parker's report, which is issued in pamphlet form, may be had free of charge from the director, United States Geological Survey, Washington, D. C.

Competition for Light Metals.

The "Ila" (Internationale Luftschiffahrt Ausstellung or International Aeronautic Exposition) now being held in Frankfurt-on-the-Main has arranged a prize competition for light metals. The arrangements have been made by the Scientific Commission of the Exposition, the president of which is Prof. Dr. Wachsmuth. We understand that the number of those who have entered the competition is quite considerable and that great interest is being taken in the results to be expected from the competition. The final date by which materials had to be submitted for tests was Sept. 15. The following conditions will be considered in the competition: The metal should have a very low specific gravity, great strength, great resistivity, and high elasticity. It should be capable of being easily machined; to prove this finished and half finished parts of motors and balloons should be submitted. The metal should also have a great resistivity against air and alkalies and acids. A gold, silver and bronze medal will be given to the firms which get the highest number of points in the competition. We hope to report on the results later on.

CORRESPONDENCE.

Strontium.

To the Editor of *Electrochemical and Metallurgical Industry*.

SIR:—A friend of mine has upon his property a limestone deposit containing a considerable quantity of strontium. Analyses of samples are as follows:

	No. 1 Sample.	No. 2 Sample.	No. 3 Sample.
SiO ₂	7.23	7.20	10.20
FeO	0.50	0.50	0.99
Fe ₂ O ₃	0.90	0.90	1.20
Al ₂ O ₃	0.55	0.63	2.80
K ₂ O	0.49	0.45	0.58
P	trace	trace	trace
MgO	1.22	2.12	0.97
SrO	5.36	4.12	13.77
CaO	44.60	44.04	34.10
CO ₂	39.20	39.29	34.54
H ₂ O	0.53	0.74	1.10
	100.58	99.99	100.25

Can any of your readers say whether this percentage of strontium is of economic value? The limestone appears to be a good one for use in the manufacture of Portland cement. Will the strontium be beneficial in this connection?

I have looked through the Transactions of various societies without finding any reference to this point, and shall be glad to learn where any information may be obtained in relation thereto.

WALLAROO, SO. AUSTRALIA. H. LIPSON HANCOCK,
General Manager, Wallaroo & Montana Mining & Smelting
Company, Ltd.

The Metallography of Iron Clarified.

BY HENRY M. HOWE.

Mr. A. Baykoff's late results¹ have opened the way to an important change in our theory of the nature of the familiar martensite needles, and through this change to a welcome simplification of the metallography of iron.

The conditions were these: The evolution of heat, both when carbonless iron cools down into region 5a of the Roberts-Austen diagram, Fig. 1, and also when it cools thence into region 5b, had indicated the existence of beta iron, something different from the gamma iron known to exist in region 4 and from the alpha iron known to exist in region 5b. The fact that this beta iron seemed to be bulkier and also more brittle and

if it has less than 0.90 per cent of carbon, then as, in cooling, it passes successively into (1) region 5a, (2) region 5b, and (3) region 6; according to our present theory, it passes successively through the stages of (1) gamma iron mechanically mixed with a progressively increasing quantity of beta ferrite, (2) gamma iron mechanically mixed with progressively increasing quantities of alpha ferrite (because the beta ferrite changes to alpha on cooling past Ar₂), and (3) alpha ferrite mixed with pearlite, which itself is in the alpha state. If it is hyper-eutectoid, i.e., if it contains more than 0.90 per cent of carbon, in cool-

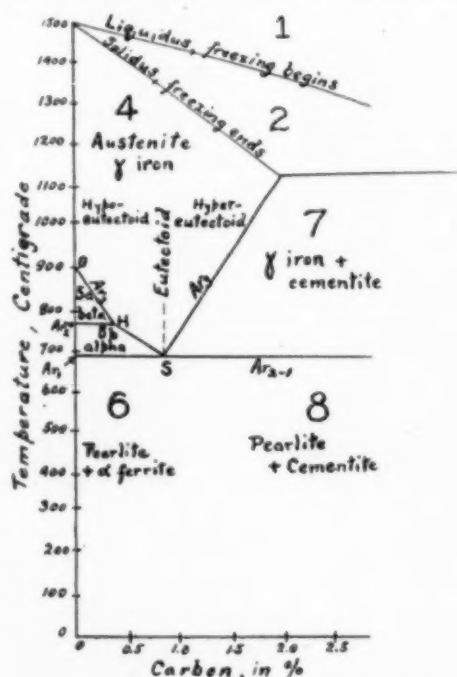


FIG. 1.—THE ROBERTS-AUSTEN OR CARBON-IRON DIAGRAM.

much harder than either gamma or alpha iron had showed that it was not a mechanical mixture of these two phases, but a distinct entity. A variety of evidence had tended to show that these martensite needles, Fig. 2, represented this beta state. But Mr. Osmond, to whom more than to anyone else our present theories are due, in his classical work on the crystallography of iron² had reported results which seemed to prove positively that these needles were not of beta, but of gamma iron. Mr. Baykoff's present results, while they do not in themselves prove that the needles are beta instead of gamma, yet overthrow Mr. Osmond's apparent proof that they are beta, by showing that his evidence is vitiated by his omitting a simple precaution, the need of which might easily pass unnoticed. It is not clear that Mr. Baykoff was aware of these results of Mr. Osmond.

In view of the inconclusiveness of the evidence of both these observers as to the nature of the needles, we are thrown back on the general attendant conditions, which certainly do not oppose, and to me, at least, seem to favor strongly, the theory that the needle structure represents beta iron. After explaining this, I will suggest a crucial experiment.

In order to understand the matter we should go back a little.

When iron is heated up into region 4 of the Roberts-Austen diagram, Fig. 1, it passes spontaneously into the non-magnetic, gamma, polyhedral condition, called austenite, of which the typical structure is shown in Fig. 3. If it is hypo-eutectoid, i.e.,



FIG. 2.—MARTENSITE NEEDLE STRUCTURE.

ing successively into (1) region 7 and (2) region 8, it passes into the stages of (1) gamma iron mixed with cementite at the line Ar₃ (ST) and (2) pearlite mixed with cementite at the line Ar₂₋₁ (SP'), in this last step either passing through or skipping over the beta state.

The point to remember is that the beta state is intermediate between the gamma, or high temperature, and the alpha, or pearlite or low-temperature state. But though this change from gamma through beta into alpha iron thus tends to occur in cooling through the "critical range" (regions 5a, 5b, and 7), it can be held in check like a bent spring by the action of what I call the "obstructive elements," carbon, manganese, and nickel. It

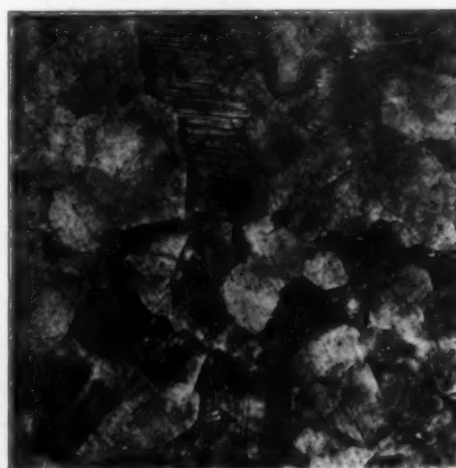


FIG. 3.—POLYHEDRAL GAMMA IRON, OR AUSTENITE STRUCTURE, IN MANGANESE STEEL.

is obstructed so strongly by manganese and nickel that it does not occur at all in steel containing 12 per cent of the former or 25 per cent of the latter metal, even if the cooling is slow. Such steel has the characteristic polyhedra of the gamma state.

The obstructive action of carbon is much feeble. Indeed,

¹Revue de Métallurgie, VI, p. 829, July, 1909.

²Annales des Mines, XVII, p. 110, and XVIII, p. 113. See especially p. 150.

carbon is not an arrester, but only a retarder of this change, so that, in order that its obstructiveness shall be effective, it has to be reinforced by cooling the metal rapidly from region 4, so as to deny the time which the change thus retarded needs in order to complete itself. In other words, carbon and rapid cooling have to co-operate in order to obstruct effectively the change from gamma through beta into alpha iron, and neither by itself has any important obstructive effect. Thus steel wholly without carbon, no matter how rapidly it is cooled from region 4, passes eventually into the alpha state, though this change may not complete itself until some time after the rapid cooling has ended. So, too, no matter how much carbon steel may contain, it passes wholly into the alpha state in slow cooling. But when the effect of carbon is reinforced by rapid cooling, the two many jointly retain apparently some 70 per cent² of the metal in the gamma state, and the remaining 30 per cent partly in the beta state. This 30 per cent has the martensite

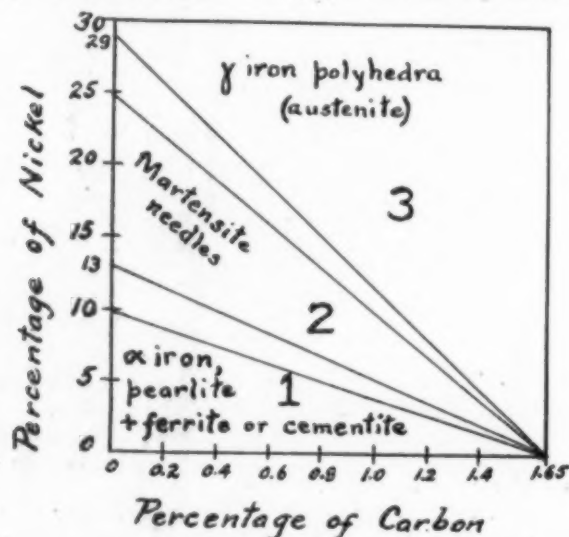


FIG. 4.—APPROXIMATE RELATION BETWEEN THE COMPOSITION AND STRUCTURE OF IRON-NICKEL-CARBON ALLOYS (NICKEL STEELS). GUILLET, "REVUE DE METALLURGIE," VOL. II, P. 351, 1905.

Note to Fig. 4. This diagram is not to be taken too literally. For instance, it implies that, with 1.65 per cent of carbon and any minutest quantity of nickel, the steel consists wholly of gamma iron (austenite), whereas in fact, even after the most rapid cooling thus far used, only about 70 per cent of the mass shows the structure of gamma iron, and of that which shows this structure no inconsiderable part may actually be alpha. Again, the diagram takes no account of the rate of cooling, but suggests that the conditions of cooling which apply to one part apply also to all the rest. But, in fact, steel, such as we have just been considering, will not contain any gamma iron at all unless cooled rapidly, whereas steel with 20 per cent of nickel and no carbon does not need rapid cooling to keep its iron in the gamma state. Nevertheless, the diagram is of value as cleverly reducing a great mass of facts to a very simple expression.

needles as to which we are asking. In order to cause so great a degree of obstruction there must be somewhere about 1.60 per cent of carbon present. If there is no more than 1 per cent, then, no matter how rapid the cooling, little, if any, gamma iron can be detected in the cold metal, which apparently consists of a mixture of beta and alpha iron, with the high magnetic retentivity which such a mixture ought to have. Such steel consists wholly of martensite needles. Here we have our first indication that these needles represent the beta state, but the existence of this beta state was first indicated by the evolutions of heat in cooling detected by Mr. Osmond.

(1) Again, manganese can reinforce the joint effect of carbon and sudden cooling. Thus, if, as in Dr. Maurer's steel,⁴ the metal contains 2 per cent of carbon and also 2 per cent of manganese, the obstruction is so great that an extremely rapid cooling, such as occurs when thin objects are quenched in ice water, seems to prevent the change from gamma iron to mar-

tensite completely, and to retain the metal wholly in the polyhedral gamma state.

(2) Again, if the gamma state has been preserved by the joint action of carbon and sudden cooling, and if the metal is permitted to escape from this state, i.e., if the change from the gamma toward the alpha state is allowed to begin by sub-cooling the quenched steel in liquid air (which seems to act by releasing the pressure under which the suddenly cooled article is), then the gamma iron changes not into alpha iron, but into the familiar martensite needles, as was first shown by Mr. Osmond.

(3) This same principle is illustrated by Guillet's diagram of nickel steel, Fig. 4, which is martensite if the sum of the carbon plus the nickel is that which corresponds to his region 2, and has the gamma iron polyhedra if this sum is great enough to correspond to region 3 of his diagram.

The thing to note here is that, when the obstruction is very great, the cold metal retains the characteristic gamma iron polyhedra. When the obstruction is only moderate, the cold metal has the equally characteristic martensite needles, which thus seem to represent a stage between alpha and gamma, presumably beta.

We have now seen that the martensite needles seem to represent a stage intermediate between alpha and gamma iron. This, as far as it goes, tends to identify them with beta iron. But I will now go farther and try to show that they are identified with (1) greater specific volume, greater brittleness, and (2) to (9) much greater hardness than those of either alpha or gamma iron, a fact which argues strongly that they are not a mechanical mixture of alpha and gamma, and hence that they really represent the intermediate beta stage which Mr. Osmond's thermal studies had shown to exist. I will then show how Mr. Osmond's results seem to contradict this conclusion, and finally try to explain them away.

(1) *Specific Volume.*—Benedicks⁵ has brought together data which show that the specific volume of martensite is greater than that of either gamma iron or alpha iron (austenite or pearlite), so that the changes of volume may be indicated graphically by a sketch like Fig. 5. Maurer, too, has since shown that the specific volume of martensite is greater than that of austenite,⁶ thus strengthening Benedicks' conclusion where it most needed strengthening, for the well-known greater volume of hardened than of annealed steel tended to show that martensite is bulkier than alpha iron.



FIG. 5.—QUALITATIVE RELATION BETWEEN THE SPECIFIC VOLUME OF AUSTENITE, MARTENSITE AND PEARLITE.

(2) *Hardness.*—Of the martensite needles and the gamma iron polyhedra found in very rapidly cooled high-carbon steel, the needles are harder than the polyhedra, as Osmond showed years ago.

(3) The needle-bearing nickel steels of Guillet's intermediate region 2 are, in general, harder and more brittle than the polyhedral gamma irons of his region 3.⁷

(4) Manganese steel containing an intermediate quantity of the obstructive elements, manganese and carbon jointly, is very much harder and more brittle than the common, polyhedral, gamma manganese steel of commerce, which contains much more of these elements.

(5) If the quantity of the obstructive elements is intermediate, and barely enough to retain the metal in the gamma state, mechanical deformation shifts it over from the regular polyhedral gamma state into the needle martensite state, and also

⁵Op. cit., Journal Iron and Steel Inst., LXXVII, pp. 224-5, 1908, II.

⁶Revue de Métallurgie, V, p. 720, Oct., 1908.

⁷Guillet's observation that low carbon niccoliferous martensite, though hard, is only moderately brittle (la fragilité n'est pas très grande), does not break the force of this argument. That under many or even under a few conditions martensite excels both austenite and alpha iron would in itself be enough to indicate that it is not a mechanical mixture of them. Rev. de Métallurgie, II, p. 351, 1905.

⁴Osmond, op. cit. XVIII, p. 150.

⁵Revue de Métallurgie, V, p. 742. Photo. 19, 1908.

makes it much harder and more brittle. This seems to be true whether we have to do with manganese alone or nickel alone, or with any mixture of them with carbon.

This change may be explained readily. The martensite state is bulkier than the gamma state. Distortion in the cold causes local pressure in one part and local tension in another, one probably alternating with the other as the deformation proceeds. The existence of tension always favors the passage into the bulkier of two possible states, and hence in this case opposes the obstructive elements, so that their obstruction thus weakened is no longer able to prevent the gamma iron from following its natural course and shifting over into the bulkier beta state. It is true that such tension may be immediately followed by pressure. But *vestigia nulla retrorsum*. This pressure is unable to reverse the change and force the beta iron back into the gamma state.

Maurer's 2 per cent manganese and 2 per cent carbon steel was so unstable that deformation readily shifted it into the martensite-needle state.*

This explanation which I give is suggested by Benedicks' brilliant discovery that release of pressure shifts gamma iron into martensite.*

(6) Again, if, as in Dr. Maurer's steel,¹⁰ the effect of the obstructive elements is insufficient to retain the metal in the gamma state unless reinforced by the rigidity of the cold state, then if the metal is slightly reheated so as to relax this rigidity it becomes very much harder, though I must admit that in this case the formation of martensite needles has not been detected.

(7) It is in the same way that I would provisionally explain the heat treatment of high-speed steel. The first quenching from an extremely high temperature preserves the gamma austenite state. The second heating starts the change from the gamma toward the alpha state, but carries it only far enough to set up the intermediate much harder martensitic beta state, and it is in this state that the tool does its wonderful cutting, the obstructive action of the tungsten, etc., retarding the transition

**Revue de Métallurgie*, V, p. 744. Photos 27 and 28, Oct., 1908.

¹⁰*Journal, Iron and Steel Institute*, 1908, II, p. 241.

Among other ways in which he proved this was by showing that, when austenite which has been preserved by very sudden cooling is further sub-cooled in liquid air and is then very suddenly reheated, as it must be when it is taken suddenly out of the liquid air and exposed to the relatively hot air at the room temperature, the sudden expansion which the outside of the specimen then undergoes throws the interior into such great tension as to permit its iron, locked in the gamma state by the sudden cooling and the pressure which accompanied the early part of that cooling, to change to the martensite state. The interior of the specimen would, at the end of the original rapid cooling, be in strong tension and the outside in strong compression, because in the latter part of that cooling the inside is cooling much more rapidly than the then cool and rigid outside. The sudden expansion of the outside on emerging from the liquid air then throws additional tension on the interior, which was already under great tension.

Now this explanation is extremely welcome, because the phenomenon was not, in my opinion, reasonably explained before.

In cooling from the gamma into the alpha state two opposing forces are at work. The gamma iron tends to change into beta and thence into alpha, but this change is opposed by molecular inertia or viscosity. The tendency to undergo the change increases with what we may call the temperature lever arm, i. e., the temperature interval between that at which the change is theoretically due and the existing temperature. As the temperature is progressively lowered, it reaches a point at which the temperature lever-arm becomes long enough, and the tendency to change therefore strong enough, to overcome molecular viscosity, and the change occurs. As the temperature sinks still farther, the tendency to change increases in strength at first more rapidly than the viscosity does, so that the change takes place with greater and greater rapidity. But there is a limit to this, and with further fall of temperature the reaction-velocity reaches a maximum, again falls off, and finally the reaction is arrested, when the temperature has sunk so low that the viscosity due to the cold completely arrests the change. This is what occurs in the hardening of steel by sudden cooling in cold water.

Now the change from austenite into martensite by sub-cooling in liquid air seemed to indicate that, though in the race from Ar 1 to 20° the viscosity had overhauled and finally distanced the effect of the temperature lever-arm, yet in continuing that race from 20° to the liquid air temperature the conqueror had somehow become the conqueror, and the reaction, arrested at 20°, now occurred. Why should this victory be thus reversed? This was certainly hard to understand, and I had long looked for some other explanation.

The welcome theory that the recurrence of the change is due to the increase of tension in heating up from the liquid air temperature can easily be tested. Quench a piece of 1.60 per cent carbon steel in ice water so as to preserve as much gamma iron as possible. Cut it into two like pieces; immerse them both in liquid air in a Dewar's flask; withdraw one and let it rise rapidly to atmospheric temperature, e. g., by moving it quickly through alcohol. Leave the other till the liquid air has evaporated, when immediately cork the flask up and allow it to rise at its natural very slow rate to atmospheric temperature. If the theory is right, the change into martensite should be less complete in this second piece than in the first, and, further, the change should be confined to the interior of the piece, which alone is thrown into tension in the heating up.

¹⁰*Revue de Métallurgie*, V, p. 723, Fig. 12, Oct. 1908.

through the beta state even at a low red heat, so that the tool will cut at this temperature for a considerable time. But in spite of this retarding of the change, it is accomplished at last, and after the metal has staid a while at this red heat so little of it remains in the hard beta state that it no longer cuts efficiently. This, at least, is an explanation, and one which is in harmony with a large body of well-known facts. Whether it is the true one I cannot now pretend to say.

(8) The martensite needles formed when gamma iron, preserved by sudden cooling, is sub-cooled in liquid air, are much harder than the austenite whence they have sprung.¹¹

(9) Finally, austenitiferous high-carbon steel quenched from a very high temperature, when tempered by slight reheating, instead of losing its hardness as martensitic hardened steels so familiarly do, becomes materially harder, according to the report of Mr. F. Robin,¹² and simultaneously loses its austenitic structure, further suggesting that the change from gamma toward alpha passes through the beta state harder than either, and hence not a mechanical mixture of the two.

And now for our puzzle. Two facts were prominently before us: First, that divergent as are the conditions under which we are able to trap iron in the needle state, those conditions always have one thing in common: that they represent a transition between the alpha and the gamma states.

Second, these needles are associated with hardness, brittleness, and specific volume greater than those of either the alpha or the gamma state, and hence not with a mechanical mixture of alpha and gamma, but with a different entity, almost necessarily beta iron by definition.

These facts were true whether we trapped the needles in passing from alpha toward gamma or in the opposite direction: whether by rapid cooling, by any combination of the obstructive elements, or by both means jointly; whether by cooling at an intermediate rate, by gentle reheating, by mechanical distortion, or by sub-cooling in liquid air.

The argument from these facts may be summed up thus: The fact that an excess of hardness, brittleness, and specific volume over those of both alpha and gamma, an excess which in itself argues the presence of the beta state, is accompanied under such widely divergent conditions by the needle state indicates very strongly that the needle state represents the presence of beta iron. Nevertheless, Mr. Osmond¹³ seemed to prove absolutely that it did not, but, on the contrary, that it was nothing but the "crystallitic" or imperfectly developed stage of gamma iron, through which it might naturally pass before forming its true crystalline polyhedra. This he did by showing that etching steel in region 4, where the iron should be wholly gamma, with either calcium chloride or hydrochloric acid, developed these needles along with the true gamma polyhedra. Indeed, in one case though a shorter etching in calcium chloride yielded polyhedra, a succeeding longer one applied to the same specimen yielded the martensite needles. This might suggest that there was no great difference in stability between the polyhedra and the needles, or even that the needles were the state to which the polyhedra tended. The polyhedra which Mr. Saniter, the inventor of the calcium-chloride method, found were often marked with needles.

The natural escape from this trouble seemed completely blocked. One's first idea would naturally be that Mr. Osmond was mistaken in his interpretation of the facts, and that the needles represented either beta iron or at least the contamination of gamma by beta iron. The needles were apparently of the isometric system, to which both gamma and beta iron belong.¹⁴ There was in this no reason, then, why these isometric needles should not represent gamma iron thus contaminated.

¹¹Maurer, *idem*, V, p. 725, Oct., 1908.

¹²*Idem*, V, pp. 901 to 903, Dec., 1908. Three curves in his Figs. 6 and 7 show this peculiarity; but the increase in hardness on subsequent cooling in the curve shown in Fig. 7 is so surprising as to call for verification.

¹³*Annales des Mines*, XVIII, p. 143, 1900.

¹⁴It is true that Le Chatelier and Ziegler got suggestions that gamma iron is hexagonal, but Osmond's evidence to the effect that it is cubic seems overwhelming. (*Bull. Soc. D'Encouragement*, X, pp. 375-6, Sept., 1902.)

none, indeed, why they should not represent beta iron itself. But this escape, as I have said, seemed completely blocked by the fact that Messrs. Osmond and Saniter got these martensite needles even after long exposures to temperatures at which the change to gamma iron seems to be extremely rapid, to temperatures not only far above Ac_3 , but even rising to 1000 deg. C. At these temperatures the metal ought to pass beyond the beta into the gamma state rapidly, for if anything is familiar it is that when steel is heated above the critical range, i. e., into region 4, it acquires the hardening power, i. e., it travels from the alpha toward the state gamma, extremely rapidly. A very striking illustration of this rapidity is given by the hardening of the upper surfaces of rails¹⁶ by the heat developed by the slipping of the driving wheels. The friction heats the skin of the rail above the critical range into region 4, and the sudden cooling by conduction of heat down into the body of the rail prevents the gamma or beta iron thus formed from slipping back into the alpha state. Now, in some of Mr. Osmond's experiments he etched the metal with hydrochloric acid at 1000 deg. C. for five minutes and yet found the polyhedra of gamma iron contaminated with needles.

How is it possible that the beta state should persist under such conditions? Why was not the metal all gamma, and hence all polyhedra without needles?

The chain of evidence seemed complete. The specimen was introduced into a tube which had been previously heated to 1000 deg. and filled with hydrogen; five minutes were allowed for the temperature to reach region 4; hydrochloric acid gas was then passed through for five minutes at this temperature to etch the specimen; then it was stopped and hydrogen was passed through for 10 minutes, in order to drive out the residual hydrochloric acid and the resultant ferrous chloride; then the heat was cut off, and the specimen allowed to cool in the furnace in hydrogen. In order to preserve in the metal, after it has cooled, the gamma structure developed by etching while in region 4 it is, of course, necessary to prevent the etching from continuing after the temperature has descended below region 4 into the beta or alpha range. Mr. Osmond's precautions—driving out the ferrous chloride and residual hydrochloric acid for 10 minutes before starting to cool from 1000 deg., and then continuing the hydrogen, apparently as a stream, during the slow cooling from 1000 deg. to the lower boundary of region 4—seemed enough to prevent any appreciable etching influence from remaining when the metal finally passed below that boundary.

They seemed enough, but apparently they were not, because when Mr. Baykoff took the additional precaution of prolonging the passage of hydrogen for driving out the hydrochloric acid from the 10 minutes of Mr. Osmond to between two and three hours, the needle markings were no longer found, if we may judge from his illustrations and from his language. The inference from this is that Mr. Osmond's 10-minute sweeping out still left enough hydrochloric acid to etch the steel rapidly, and that when the steel cooled to below region 4 and changed from gamma to beta iron, the needle structure which we have so many reasons to regard as the structure of beta iron became developed by these unexpelled remains of hydrochloric acid. So this discordant evidence of Mr. Osmond's, which seemed to prove that the needle structure belonged to gamma iron is explained away really in a very simple way, and the theory that the needle structure represents beta iron becomes tenable.

When we have admitted this much with regard to these experiments of Mr. Osmond, we may go a step farther and accept a like explanation of the results less easily explained, which both he and Mr. Saniter reached. Both these gentlemen found that when steel was heated well into region 4 in molten calcium chloride and then quenched in water, it had the needle markings in addition to the gamma iron polyhedra. In one case Mr. Osmond heated his specimen for 130 seconds in cal-

cium chloride, at the end of which it had reached a yellow heat, and then quenched it in water, when it still showed the characteristic martensite needles.¹⁷ Now it would certainly be surprising if, as Mr. Baykoff assumes, the calcium chloride were able to etch the needle structure as deeply as it was etched in the calcium chloride experiments of both Mr. Osmond and Mr. Saniter, in the very brief interval between the time when the metal, while under water, cooled into the beta iron range and the time when it became too cold to be further etched. But then the needle markings may have been etched when the metal was heated up through the beta iron range, and they may have persisted unobliterated through the etching in the gamma iron state of region 4.

In Mr. Osmond's other experiments, in which the metal was cooled down slowly in the furnace, there would be plenty of time in the passage through the beta state for the residual hydrochloric acid to do its work of etching if we only make the reasonable admission that the structure does not leap from the gamma polyhedral state to that of pearlite, but passes through the martensite needle state. That under these conditions the metal should remain an appreciable time in the beta iron range is natural enough.¹⁸ Were it not for this it would be impossible to harden steel by sudden cooling, i. e., to retain the martensite needles and harden the steel. The magnetic phenomena support this view.

Two straws may be noted which agree with this interpretation, that the needle markings in the specimens of Messrs. Saniter and Osmond are due to the action of the etching reagent while the metal was passing through the beta iron range into or away from region 4. These are as follows:

First, the slowness of the needle markings in Mr. Osmond's specimens etched with hydrochloric acid in a tube with subsequent attempt at expelling the hydrochloric acid before cooling below region 4 (Ar_3). The needle markings were so fine that they were not seen with a magnification of 25 diameters, though here the gamma polyhedra stood out very strongly.¹⁹ This is as if the etching which had developed the polyhedra was very strong, while that which developed the needles was very weak, just such as we might expect from the small quantity of hydrochloric acid which would be left after his 10-minute sweeping out. This indication is of minor importance.

Second, Mr. Saniter,²⁰ in etching steels of different carbon contents in calcium chloride and then quenching in water, developed polyhedra alone without needle structure when the carbon content was 0.10, but, as the carbon content rose in his different specimens, the needle structure became more and more marked, and was very strong when the carbon content reached 1 per cent. In the same way Mr. Osmond notes that the martensite needles tend to disappear in pure iron, but their presence is favored by the presence of a little carbon.²¹

Now this is just what we ought to expect, on the theory that the needle structure is due to etching the metal in the beta state, whether in the rapid cooling from Ar_3 down or in the heating from Ac_2 up, because the higher the carbon-content the slower is the passage through that state. This is familiar to us all in the fact that the hardening power and the prominence of the needle markings increase with the carbon-content.

But, though Mr. Baykoff's evidence thus seems to me to make the theory that the needle structure represents the beta state tenable, and thus to give a simpler interpretation to all our evidence, yet I must admit that this evidence is really explicable on the other theory that these needles represent an assumed crystallitic state of gamma iron. This, like the beta state, would be one of transition between gamma and alpha. The needles represent transition; they may conceivably repre-

¹⁶Op. cit., XVII, p. 143, Pl. IV, Figs. 45 and 46.

¹⁷Compare Mr. Osmond, the Metallographer, II, p. 169, and the author, *idem*, II, p. 257.

¹⁸Osmond et Cartaud, *Annales des Mines*, XVIII, pp. 139-140, Pl. V, Fig. 8, Pl. VI, Figs. 1, 2 and 4.

¹⁹Journal Iron and Steel Inst., LII, pp. 124-5, Pl. V, 1897, II.

²⁰Op. cit., XVIII, p. 145, 1900.

²¹J. E. Howard, *Trans. Am. Soc. Testing Materials*, VIII, p. 62, 1908.

sent either the beta state or the crystallitic form of the gamma.

I point out this difference, that the proof of the existence of the beta state, in the excess of hardness, brittleness, and specific volume over both the gamma and the alpha states, and in the retardations at A 3 and A 2, is very strong, while the proof of the existence of the crystallitic state of gamma iron seems to me still lacking. It was invoked to explain away the apparent coexistence of the needle structure with the gamma state, a coexistence which has no longer to be explained, because Mr. Baykoff's results show that there may be no such coexistence. Nevertheless, should one postulate this coexistence and refer the needle marking to the crystallitic phase of the gamma state, he would be hard to silence, though he would have to explain how it comes to represent both the upbuilding of the gamma polyhedra out of the alpha state, and also the downfall of those polyhedra when the gamma changes back to the alpha state.

A crucial test of this question should be easy. Let one proceed, with all Mr. Baykoff's precautions, to etch low carbon steel, say, of 0.10 per cent of carbon, in the lower part of region 5a. Here it ought to consist of envelopes of beta ferrite enclosing kernels or meshes of gamma iron (austenite). The carbon-content should be low, and the temperature but little above A 2, in order that the quantity of the beta ferrite should be large. The temperature should be rigidly stationary, lest the quantity of beta ferrite vary rapidly, dissolving in the gamma iron and again reprecipitating as the temperature rises and falls, with possible obliteration of the needle markings as fast as they form.

If the experiment is conducted skilfully, and if it is true that the needles represent beta iron, then the envelopes should have the needle markings, and the kernels should have the gamma iron polyhedra. In order to get large and hence easily identified envelopes of beta iron, it would probably be well to heat the specimen first in hydrogen to 1100°, and cool it down in the tube to slightly above Ar 2, holding it there till the end of the etching and of the subsequent outswEEPing of the etching gas.

The inferences which I draw are as follows:

- (1) The natural theory that the needle structure represents beta iron again becomes tenable.
- (2) It is the theory to be adopted until disproved, because it is the simpler.
- (3) On this, the probable theory, the needle markings found by Messrs. Osmond and Saniter indicate that the passage through the beta state in both heating and cooling is slow, as indeed Mr. Osmond's cooling curves had indicated.
- (4) The theory that these markings represent the crystallitic state of gamma iron is still tenable, but it seems to introduce a needless complication in postulating such a crystallitic state.
- (5) The truth of these two theories is easily tested by a crucial experiment, which I commend to our young men.

Calcium Carbide.*

By C. A. HANSEN.

This work was undertaken with the intention of studying the reaction $\text{CaO} + 3\text{C} = \text{CO} + \text{CaC}_2$ with particular reference to the equilibrium CO pressure at various comparatively low temperatures.

Furnace.—The furnace used was one designed by Arsem, of this laboratory, and described by him. (*Jour. Am. Chem. Soc.*, XXVIII, 922, 1906). A cut showing cross section is reproduced in Fig. 1. The furnace was calibrated against copper and platinum in the manner described by Arsem at 1 mm pressure and at 28 mm pressure. (See Fig. 2.)

The copper was melted in a graphite crucible, the melting point taken as 1084 deg. C.

Copper 1 mm.	
Melting Pt.	Freezing Pt.
2.5 kw.	2.3 kw.
2.5 kw.	2.3 kw.
Mean 2.4 kw.	

28 mm.	
2.6 kw.	2.4 kw.
2.6 kw.	2.4 kw.
Mean 2.5 kw.	

Platinum 1 mm.	
Melting Pt.	Freezing Pt.
5.0 kw.	—
5.0 kw.	—
Mean 5.0 kw.	

28 mm.	
5.1 kw.	—
5.1 kw.	—
Mean 5.1 kw.	

The platinum was melted in a thorium oxide crucible which was separated from the graphite crucible support by a tungsten washer and the melting point was taken as 1780 deg. C.

The melting point is determined by the appearance of a black spot on the surface of the metal bead, a portion of the meniscus reflecting no light vertically through the mica win-

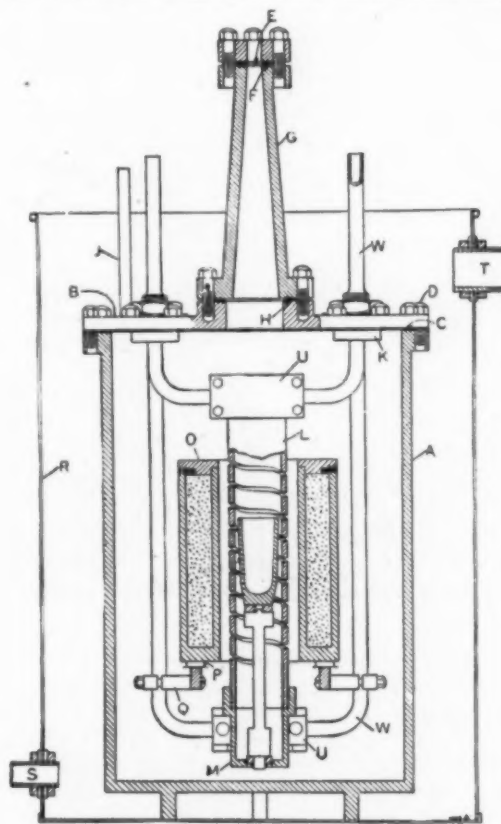


FIG. 1.—ELECTRIC FURNACE.

dow (E). The freezing point is determined by the disappearance of this black spot, due to wrinkling of the metal surface on solidifying. In the platinum determination the black spot refuses to disappear on cooling, so that only the melting point reading can be taken. In this case the platinum was considered at its melting point when the metal began to collect in beads on the wire used.

The temperature, according to these determinations, falls off not more than 20 deg. at constant power input as the pressure increases from 1 mm to 28 mm when the mean temperature is about 1800° C.

As a test for leakage, and gas in the graphite apparatus within the furnace, the furnace was sealed at the melting point of platinum.

Time, Minutes.	Kw.	Pressure.
0	5.0	1.0 mm.
30	5.0	1.0 mm.
35	5.1	28. Let in air.
65	5.1	28.

As a further test for leakage the furnace was sealed cold on a Friday noon, at 1 mm pressure. The following Monday morning the gauge registered 3 mm pressure.

Exhausting Apparatus.—This consisted of a 5-10 mm pressure rough pump line, and a Geryk pump with two cylinders in series, capable of reducing pressure to less than 0.5 mm. The furnace was always exhausted on rough vacuum line, then

*A paper read before the International Congress of Applied Chemistry, London, 1909.

shifted over to the Geryk pump. The Geryk had cylinders $2\frac{1}{2}$ -in. diameter, 5-in. stroke and operated at 35 r.p.m.

The pressure was measured on an ordinary mercury manometer.

CO Test.—A small gas flame was allowed to play over the mouth of the pump exhaust tube. A pressure of 2 mm CO in the furnace results in spurts of characteristic blue flame, an inch or two in length when the exhaust gas was thus ignited.

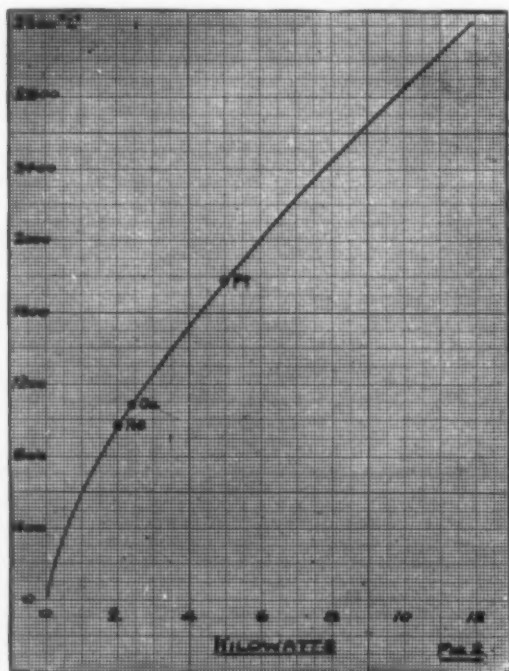


FIG. 2.—CALIBRATION CURVE.

Charge.—90 parts of pure lime, 38 parts of "1340" Acherson graphite, 50 parts hard pitch were ground to an impalpable powder in a small hardened steel mill. The powder was then ground to the consistency of a thick cream with Kahlbaum's c.p. benzol and dried to 150°C ., with constant stirring. The final powder was then pressed, at about 40 tons pressure, into pellets 1 in. high and 1 in. diameter and carbonized by baking to 800°C . in a small electrically heated muffle. The object of using pitch and benzole was to thoroughly coat each lime particle with carbon and so secure a maximum contact surface between

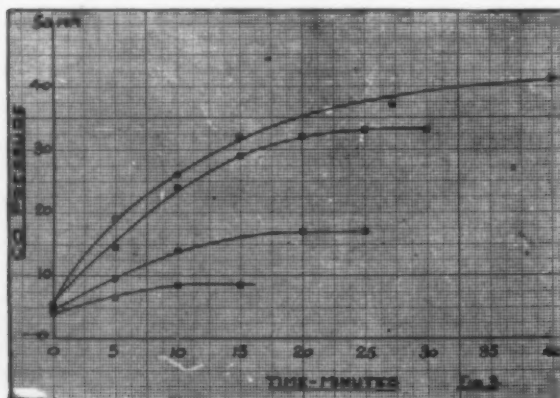


FIG. 3.—PRESSURE CURVES.

the reagents. A pellet so treated, then fired in a vacuum for four hours at 1000°C ., to drive off any CO_2 , hydrocarbons, etc., weighed about 16 grams and analyzed:

57.6 CaO
43.2 C

This corresponds to

$\left. \begin{array}{l} 57.6 \text{ CaO} \\ 37 \text{ C} \end{array} \right\}$ in proportion to form CaC_2
6.2 C excess

Procedure.—The intention was to heat a pellet to a definite temperature, seal off the furnace and take pressure readings, the equilibrium pressure being indicated by several consecutive equal pressure readings.

A pellet was introduced into the furnace, in a graphite crucible, heated to 1000°C . for four hours to insure complete removal of the CO_2 in the lime, volatile pitch hydrocarbons and the complete reduction of a small amount of Fe_2O_3 (0.2 per

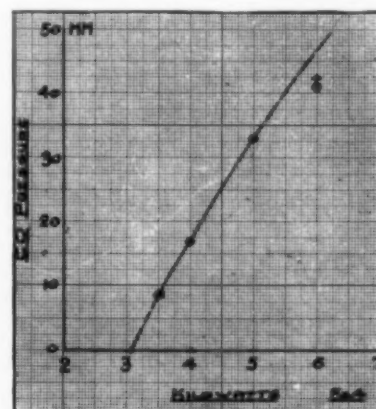


FIG. 3.—PRESSURE CURVE.

cent) in the pitch and graphite. The run then proceeded as follows:

Time.	Kilowatts.	MM. Pressure.	
9:00 a. m.	2.0	8	
1:00 p. m.	2.0	3	
1:00	3.0		
1:15	3.0	3	
1:15	3.5		
1:30	3.5	4	Shut off pump after pressure reading.
1:35	3.5	6.5	
1:40	3.5	8.5	
1:50	3.5	8.5	Opened to pump after pressure reading.
1:53	4.0	4.5	
2:03	4.0	4.5	Shut off pump.
2:08	4.0	9.5	
2:13	4.0	14	
2:23	4.0	17	Opened to pump.
2:30	4.0	17	
2:32	4.5	6	
2:40	4.5	5.5	
2:50	4.5	5.5	
2:50	5.0		
2:56	5.0	5.5	Shut off pump.
3:01	5.0	17	
3:06	5.0	24	
3:11	5.0	29	
3:16	5.0	32	
3:21	5.0	33	Opened to pump.
3:26	5.0	33	
3:35	6.0	5	
3:40	6.0	5	Shut off pump.
3:45	6.0	19	
3:50	6.0	26	
3:55	6.0	32	
4:07	6.0	37	Opened to pump.
4:20	6.0	41	
4:25	6.0	3	
4:30	6.0	2	
4:40	6.0	1	Shut off power.

The increase in pressure with time during the various intervals when the pump was disconnected from the furnace is shown in diagram, Fig. 3.

It must be kept in mind that the contact surface between reagents decreased as the reaction progressed, so that the initial slopes of these curves are not a measure of the true reaction velocities at the corresponding temperatures. In fact, at the last the reaction velocity was so low that I did not wait for the equilibrium pressure to be established.

The equilibrium pressures are plotted against both kilowatts and temperature (as taken from Fig. 2) in Figs. 4 and 5. Extrapolated, these curves indicate reaction between CaO and C , at a temperature as low as 1275°C .

Analysis of the product of this run:

42.7 CaC₂ (149.5 cc. C₂H₂ per gram)
3.0 CaO
50.6 C

The high carbon percentage necessarily means loss of calcium from the charge, either by direct distillation of calcium produced by the reaction $\text{CaO} + \text{C} = \text{Ca} + \text{CO}$, or by the formation and subsequent decomposition of CaC₂. In either case, the calcium and carbon would leave the crucible in atomic proportions, so it is possible, from analysis before and after firing, to calculate the disposition of the materials fired.

On the basis of a 100 gram charge, we obtain

7.7 g. C } not acted upon.
1.42 g. CaO }
20.1 g. CaC₂ recovered.
43.2 g. CaC₂ formed and decomposed, giving
27 g. Ca, which volatilized
16.2 C recovered.
27.7 g. CO pumped off.

According to this hypothesis the recovered carbide amounted to only 31.7 per cent of that formed. Loss in weight, 54.6 per cent.

To verify the results obtained in the first run, I attempted to show, first, that no reaction would occur at 1450 deg. C. if the pump were sealed off; secondly, that if the pump were

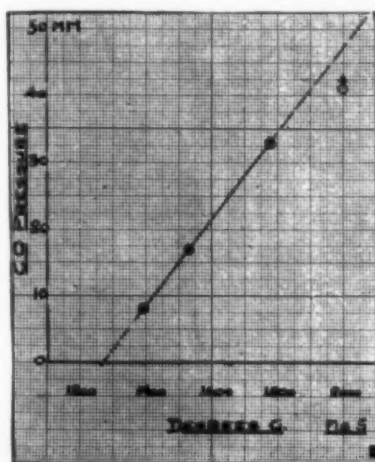


FIG. 5.—PRESSURE-TEMPERATURE CURVE.

connected and the CO pressure kept below the equilibrium value, the reaction would go on.

A pellet was treated at 1000 deg., as before, the furnace sealed at 1 mm, power increased to 3.7 kw (1450 deg. C.) and kept at this value for six hours. Analysis gave results identical with those on the unfired pellets.

The same pellet, less the analysis sample, was returned to the furnace and heated similarly for six hours, with the pump connected. The pressure ranged from 3 mm, at the start, to less than 0.5 mm at the end, and analysis showed

40.75 CaO
55.4 C

Less than 1 cc. of C₂H₂ was obtained from 0.5 gram of the product, although it smelled strongly of acetylene. The acetylene test was made immediately after removal of product from furnace. The pellet was then allowed to stand around in the atmosphere for a short time, which undoubtedly explains the incomplete analysis. The absorption of CO₂ and H₂O cannot alter the ratio of lime to carbon, so we are justified in increasing the values to

42.3 per cent CaO
57.7 per cent C

Disposition of 100 grams charge:

21.45 Ca } lost in furnace. < volatile.
15.00 CO } pumped off.

26.70 CaO } retained in crucible.
36.75 C }

It is perfectly evident that reaction does go on at 1450 deg. if the pressure is kept below the critical value, and that it does not go on if the pressure exceeds the critical value. We have not, however, shown whether calcium distills without forming calcium carbide, or whether the calcium carbide is formed, then dissociated. The residual carbon from the pellet, heated to 1450 deg. in the sealed furnace, obviously contained much of the gritty, amorphous carbon left behind by the pitch. The residual carbon from the pellet heated to 1450 deg. in the furnace with pump connected could be rubbed into a coherent, graphitic sheet with a spatula. This test is an unsatisfactory one for the formation and decomposition of CaC₂ in so far as the pitch carbon would be the first to be gotten rid of, because of the method of making up the pellet, even if the amorphous carbon would not be selectively oxidized.

A separate experiment was made in which I tried to dissociate commercial calcium carbide at 1450 deg. The carbide available was of rather poor quality, and the test unsatisfactory as a result of this poor quality. The carbide, before heating evolved 285 cc. C₂H₂ per gram. After firing six hours, at 1450 deg., it evolved 210 cc. per gram, and the loss in weight was 2.25 grams in 12.05 grams. Calculating the loss as calcium, the fired product should evolve 222 cc. per gram. Analysis of the fired product did not give nearly so satisfactory a result as the gas evolution. Apparently, the carbide was very non-uniform in composition. This work is to be carried on to a more satisfactory conclusion.

Thanks are due B. R. von Sholly, of this laboratory, for the analytical work.

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Mathematics and Physics.

In his presidential address, delivered to the British Association at Winnipeg on Aug. 25, Sir J. J. THOMSON urges strongly the greater study of mathematics. We quote from his address as follows:

"The specialization prevalent in schools often prevents students of science from acquiring sufficient knowledge of mathematics; it is true that most of those who study physics do some mathematics, but I hold that, in general, they do not do enough, and that they are not as efficient physicists as they would be if they had a wider knowledge of that subject.

"There seems at present a tendency in some quarters to discourage the use of mathematics in physics; indeed, one might infer, from the statements of some writers in quasi-scientific journals, that ignorance of mathematics is almost a virtue. If this is so, then surely of all the virtues this is the easiest and most prevalent.

"Two points of view are better than one, and the physicist who is also a mathematician possesses a most powerful instrument for scientific research with which many of the greatest discoveries have been made; for example, electric waves were discovered by mathematics long before they were detected in the laboratory. He also has at his command a language clear, concise, and universal, and there is no better way of detecting ambiguities and discrepancies in his ideas than by trying to express them in this language.

"Again, it often happens that we are not able to appreciate the full significance of some physical discovery until we have subjected it to mathematical treatment, when we find that the effect we have discovered involves other effects which have not been decided, and we are able by this means to duplicate the discovery. Thus James Thomson, starting from the fact that ice floats on water, showed that it follows by mathematics that ice can be melted and water prevented from freezing by pressure. This effect, which was at that time unknown, was after-

wards verified by his brother, Lord Kelvin. Multitudes of similar duplication of physical discoveries by mathematics could be quoted.

"I have been pleading in the interests of physics for a greater study of mathematics by physicists. I would also plead for a greater study of physics by mathematicians in the interest of pure mathematics.

"The history of pure mathematics shows that many of the



FIG. 1.—HORN LIGHTNING ARRESTER.

most important branches of the subject have arisen from the attempts made to get a mathematical solution of a problem by physics. Thus the differential calculus arose from attempts to deal with the problem of moving bodies. Fourier's theorem resulted from attempts to deal with the vibrations of strings and the conduction of heat; indeed, it would seem that the most fruitful crop of scientific ideas is produced by cross-fertilization



FIG. 2.—FLAME FOR NITROGEN FIXATION.

between the mind and some definite fact, and that the mind by itself is comparatively unproductive.

"I think, if we could trace the origin of some of our most comprehensive and important scientific ideas, it would be found that they arose in the attempt to find an explanation of some

apparently trivial and very special phenomenon; when once started the ideas grew to such generality and importance that their modest origin could hardly be suspected. Water vapor we know will refuse to condense into rain unless there are particles of dust to form nuclei; so an idea before taking shape seems to require a nucleus of solid fact round which it can condense.

"I have ventured to urge the closer union between mathematics and physics because I think of late years there has been some tendency for these sciences to drift apart, and that the workers in applied mathematics are relatively fewer than they were some years ago. This is no doubt due to some extent to the remarkable developments made in the last few years, in experimental physics on the one hand and in the most abstract and metaphysical parts of pure mathematics on the other. The fascination of these has drawn workers to the frontiers of these regions who would otherwise have worked nearer the junction of the two.

"In part, too, it may be due to the fact that the problems with which the applied mathematician has to deal are exceedingly difficult, and many have felt that the problems presented by the older physics have been worked over so often by men of the highest genius that there was but little chance of any problem which they could have any hope of solving being left.

"But the newer developments of physics have opened virgin ground which has not yet been worked over and which offers problems to the mathematician of great interest and novelty—problems which will suggest and require new methods of attack, the development of which will advance pure mathematics as well as physics.

"I have alluded to the fact that pure mathematicians have been indebted to the study of concrete problems for the origination of their most valuable conceptions; but though no doubt pure mathematicians are in many ways very exceptional folk, yet in this respect they are very human. Most of us need to tackle some definite difficulty before our minds develop whatever powers they may possess. This is true for even the youngest of us, for our schoolboys and girls, and I think the moral to be drawn from it is that we should aim at making the education in our schools as little bookish and as practical and concrete as possible."

The Innsbruck Plant for Nitric Acid from Air.

Besides the Birkeland-Eyde process and the new process of the Badische Company, which are both in successful commercial operation in Norway, there is a third process for the fixation of atmospheric nitrogen, working on a large scale in Patsch near Innsbruck in Tyrol. The water power of the Sill is utilized. The inventors of the process used at this plant are the two brothers, H. Pauling and G. Pauling, and the process is owned by the Salpetersäure-Industrie-Gesellschaft in Gelsenkirchen. The process has recently been described by Dr. FRANZ RUSS in a paper read before the Society of Austrian Chemists. The full paper is published in *Osterr. Chemiker Zeitung*, No. 11, 1909, and in the issue of Aug. 1 of the *Zeitschrift für Elektrochemie*.

The Pauling process employs arcs produced between two electrodes which are curved like the electrodes of the so-called horn lightning arresters (Fig. 1). The two horns are nearest together at the bottom and it is there that the arc is lighted. On account of the rising hot air the arc rises upward, becomes longer and is broken once for every half period of the alternating current. A new arc is then lighted at the bottom, and so on.

If an air current is blown with high speed between the electrodes of such a lightning arrester, the arc is still further blown away, so that it is possible to produce in this way arcs of considerable length. Fig. 2 shows such a flame arc of 200 kw capacity, as used on a large scale. In practice the minimum distance between the electrodes—at the point where the arc is

lighted—must be made large enough to blow the enormous quantities of air through. That means, the voltage required to light the arc over this minimum distance must be relatively high.

A special method of lighting the arc is used, as shown in Fig. 3. *a* are the two electrodes in horn form. At their lower

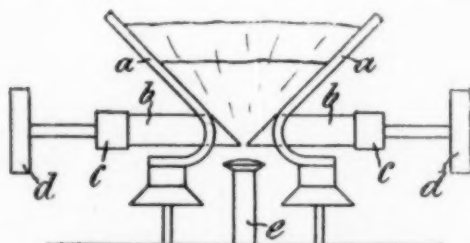


FIG. 3.—DEVICE FOR LIGHTING THE ARC.

end a slit is cut through each electrode and thin blades *b* are placed through these slits. The distance between the ends of these two blades can be adjusted by hand, by means of *d*, *c* being a piece of insulating material. Since these blades are very thin, they do not disturb the motion of the air and the latter can enter into the arc with full effect.

The main electrodes are so placed that an air current of about 40 mm width passes through the narrowest point. The preheated air-current is blown into the flame from a tube *e* in such a way that the air current, when leaving the tube, is diverged and passes along the electrodes along their whole length. The advantages of the thin blades are that the main electrodes *a* are absolutely fixed and that the flame may be easily regulated. Such a flame is electrically very "quiet" and appears to the observer to be stable. The length of the flame

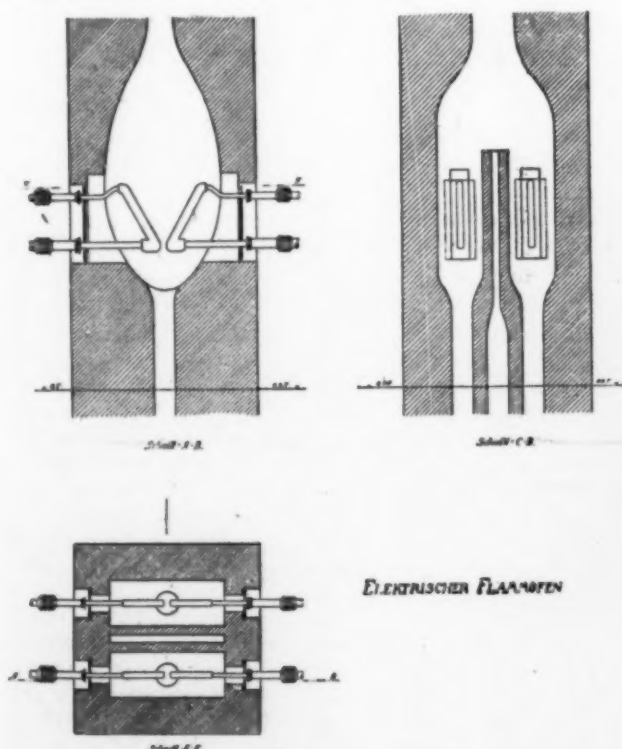


FIG. 4.—SECTIONS OF FURNACE.

in practice is about 1 m. The electrodes are made of iron and are water-cooled and their life is about 200 hours. The life of the thin blades *b* is shorter and it is necessary to push them nearer together from time to time so as to maintain the proper distance between their ends.

It is well known that the hot air containing nitrogen oxides

must be cooled very quickly in order to prevent the nitrogen oxides from being again dissociated. This cooling effect is produced by passing "cooling air" into the upper part of the



FIG. 5.—FURNACE.

flame from the side. This "cooling air" is taken from the cooled gas mixture before it enters the condenser.

This "cooling air" is supplied into the flame at a lower speed than the main air current. It has a suction effect on the arc, so that the latter is lengthened and broadened.

By the Pauling process a concentration of about 1.5 per cent of nitrogen oxide is obtained on a large scale.

Each furnace built of brick contains two arcs. The type of furnace used at present is shown in three sections in Fig. 4. The capacity of such a furnace is 400 kw, while the voltage is



FIG. 6.—PORTION OF FURNACE-ROOM.

4000. Six hundred cubic meters of air pass per hour through the furnace, not including the "cooling air."

At present 24 furnaces are in operation in the Innsbruck plant. Fig. 5 shows one of the furnaces and Fig. 6 part of the present furnace house. Fig. 7 is a view of a 400-kw flame.

Little attendance is required. One man is sufficient for six furnaces.

In order to supply a number of arcs from one and the same circuit a special arrangement is used (German patent, 193,366; Austrian patent, 30,533).

Two arcs are used in series in each furnace and there is a

very high resistance inserted between the center pole and one of the outer poles. The full voltage is therefore impressed first on the other side (between the other outer pole and the center pole) and an arc is formed there. The voltage in this arc then decreases quickly and almost the whole voltage is now impressed on the other side so that the second arc is started. In the moment when the second arc is lighted the circuit of the machine is directly closed through the two arcs in series so that a long arc can be formed.

More recently this method has been further modified. The voltage for lighting the arc is much higher than the voltage otherwise needed in regular operation. The voltage for lighting the arc is, therefore, now supplied by an auxiliary circuit of correspondingly high voltage, but of low wattage, while the

latter the nitrogen oxides are utilized which still remain in the air after absorption with water.

Sixty grams of HNO_3 are produced per kw-hour in the Pauling process.

The 24 furnaces at present installed in the Innsbruck plant have a capacity of together 15,000 hp. Two other plants, each

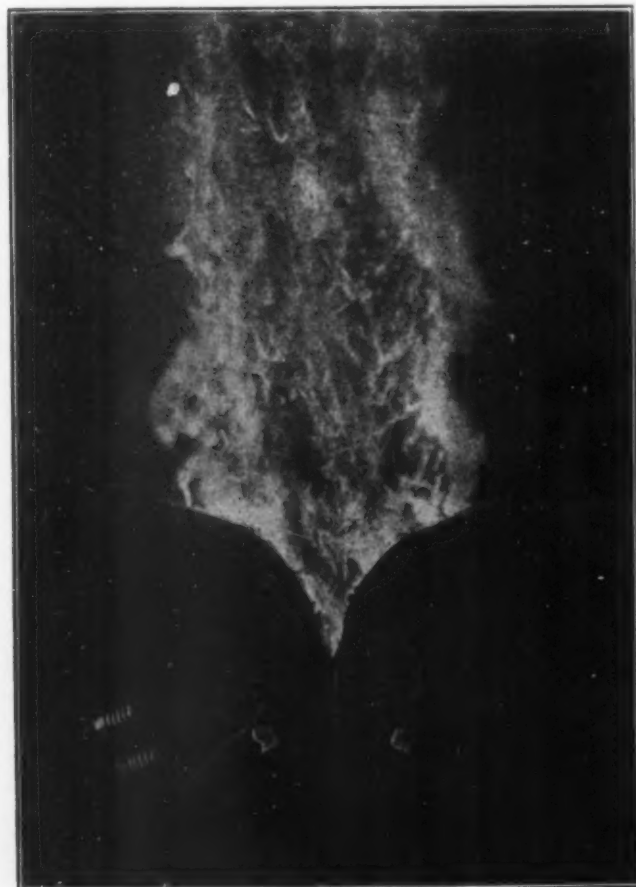


FIG. 7.—400-KW FLAME.

voltage for regular operation is less. Provision is made to prevent a discharge of the auxiliary high-tension circuit into the circuit for regular operation. It is possible to operate any number of furnaces in parallel from the same circuit, and this can be done satisfactorily without any disturbing effect of one arc on the others.

The gases pass out of the furnaces at a temperature of about 700 deg. C. to 800 deg. C. and are then transformed into nitric acid and sodium nitrite.

One of the most important technical problems—and at the same time a very difficult one—is the rational utilization of the heat contained in the furnace gases. This is used for pre-heating the air blown into the furnaces and for the evaporation of the nitric acid and the nitrite. The nitric acid is condensed in a system of chemical stoneware pipes and towers. An acid of 35 to 40 per cent is produced. For the concentration to commercial acid of 60 per cent, the heat of the furnace gases is utilized. The plant for making nitric acid is connected, as mentioned, with the plant for making sodium nitrite. In the



FIG. 8.—NITRIC ACID WORKS AND ELECTRIC POWER PLANT.

of 10,000 hp, for carrying out the same process, are in course of erection, one in southern France and the other in northern Italy.

Current is obtained from the Sill water-power plant of the Municipal Electricity Works of Innsbruck.

An old view of the nitric acid plant and the electricity works is shown in Fig. 8, which shows the pipe line at the right, and



FIG. 9.—INNSBRUCK NITRIC ACID WORKS.

the nitric acid factory in the front. The two small frame houses are the experimental plant, while the large buildings are the 15,000-hp factory. Fig. 9 is a more recent view of the works.

Conductivity, Porosity, and Gas Permeability of Refractory Materials.*

By S. WOLODINE AND A. L. QUENEAU.

(Concluded from page 383.)

Porosity.

The porosity of clay products may be defined either by the volume of the pores expressed in percentage of the total volume¹ or by the ratio of the difference in weight between the weight of the sample saturated in water and the weight of the same sample dried in a steam oven, to the weight of the sample; this ratio is given in percentage of the dry weight.²

Let P_s be the weight of a sample dried to constant weight, P_m the weight of the sample saturated in water, and P_e the weight of the sample immersed in water. Then according to the second definition the porosity P_p will be

$$P_p = \frac{(P_m - P_s) 100}{P_s}$$

and according to the first definition

$$P_v = \frac{(P_m - P_s) 100}{(P_s - P_e) + (P_m - P_s)} = \frac{(P_m - P_s) 100}{(P_m - P_e)}$$

where $P_m - P_s$ = volume of the pores.

$P_s - P_e$ = volume of the matter without pores. Knowing P_s , P_m , P_e , the true density (true δ) and the apparent density (apparent δ) are easily obtained.

$$\text{true } \delta = \frac{P_s}{P_s - P_e}$$

$$\text{apparent } \delta = \frac{P_s}{(P_s - P_e) + (P_m - P_s)} = \frac{P_s}{P_m - P_e}$$

To obtain P_s , P_m and P_e three weighings were necessary: First, of the dry specimen; second, of the same specimen boiled in water to expel all the enclosed air and then cooled in water under reduced pressure; third, of the same specimen saturated in distilled water.

The specimens used in these determinations, obtained from the bricks used in the heat conductivity tests, were of a form more or less regular and of about 10 gr. in weight; they were boiled in a beaker for an hour in distilled water, the beaker and contents were then allowed to cool under reduced pressure. If no air bubbles appeared during a second boiling, the sample after cooling was weighed in water by means of an hydrostatic balance. The specimen was then weighed in air in weighing bottles after carefully removing all superficial water with blotting paper; this determination of P_m was repeated several times; the different results were then averaged.

*A paper read before the London Congress of Applied Chemistry.
¹Rien-Clays, 1906.
²Le Chatelier Bulletin de la Société d'Encouragement, S. 5, 1898, p. 1317.

TABLE III.
CONDUCTIVITY, DENSITY, POROSITY AND PERMEABILITY OF REFRACTORY MATERIALS.

No.	Material	Mark	CONDUCTIVITY		DENSITY		PERMEABILITY			Tempera- ture of Burning
			Gr-cal. per sq. cm. per 1° Diff.	Kg-Cal-Hr. per sq. m. per m. per 1° Diff.	True δ	Appar- ent δ	Porosity in % of Vol.	Cm ³ -sec. per sq. cm. per cm.	Lit-hr. per sq. m. per m.	
1	Fire brick	1	.0030	1.07	...	...	...	.0155	5.58	1,200°
2	"	RA-5	.0037	1.32	2.61	1.81	30.8	.0409	14.72	1,050
3	"	RA-9	.0050	1.81	2.5	1.9	24.1	.069	24.84	1,300
4	"	RB-5	.0035	1.25	2.59	1.81	29.4	.105	37.84	1,050
5	"	RB-9	.0042	1.50	2.55	1.78	30.2	.295	106.2	1,300
6	Checker brick	2	.0034	1.21	...	...	...	...	...	...
7	"	4	.0039	1.42	2.65	1.91	27.8	.0465	16.74	...
8	Gas report brick	20-3	.0038	1.37	2.58	1.87	27.3	.0599	21.56	...
9	"	20-5	.0038	1.36	...	...	...	.0498	17.93	...
10	Bauxite	Bx-5	.0031	1.11	3.22	1.89	41.5	.0292	10.50	1,050
11	"	Bx-9	.0033	1.19	3.12	1.92	38.4	.212	76.39	1,300
12	Silica	S-5	.0020	.71	2.75	1.58	42.58	.0092	3.32	1,050
13	"	S-9	.0031	1.12	2.62	1.50	42.9	.536	192.9	1,300
14	Magnesia	M-5	.0058	2.08	3.07	2.0	35.1	.517	186.1	1,050
15	"	M-9	.0065	2.35	3.39	2.0	41.0	.0097	3.49	1,300
16	Euboea magnesia	M	.0071	2.54	3.50	2.4	31.5	.015	5.40	...
17	and Vallauris clay	MV-47	.0036	1.28	...	...	...	...	...	...
18	"	MV-50	.0035	1.27	...	...	...	.025	9.0	...
19	"	MV-56	.0029	1.05	3.39	2.02	40.3	.0084	3.03	...
20	Glass pot*	P-1	.0025	.89	...	...	...	0	0	9
21	"	P-2	.0025	.89	2.65	1.86	29.7	.0008(P)	.30	1,200
22	"	P-3	.0045	1.62	2.50	1.95	21.9	.0031	1.11	1,600
23	"	B-4	.0027	.96	2.52	1.77	29.4	0	0	...
24	"	B-5	.0027	.96	2.53	1.71	30.4	.0028	1.02	1,200
25	Carborundum	CA-5	.0145	5.22	...	...	...	...	...	1,050
26	"	CA-9	.0231	8.32	...	...	...	...	...	1,300
27	"	C-5	.0033	1.20	3.02	1.96	35.2	.0053	1.90	1,050
28	"	C-9	.0145	5.22	2.83	1.96	30.6	.0043	1.55	1,300
29	Chromite	Ch-1-23	.0069	2.48	...	...	...	...	...	...
30	"	Ch-1-36	.0066	2.37	...	...	...	...	...	...
31	"	Ch-1-39	.0062	2.25	...	...	...	...	...	...
32	"	Ch-2-59	.0057	2.05	4.06	3.19	21.3	.0568	20.45	...
33	"	Ch-2-26	.0055	1.98	4.03	2.98	26.1	.106	38.16	...
34	"	Ch-2-45	.0047	1.69	...	...	...	...	...	...
35	"	Ch-2-60	.0054	1.96	...	...	...	...	...	...
36	Chromite, clay binder	FA-5	.0028	1.00	3.38	2.31	31.7	.0032	1.15	1,050
37	"	FA-9	.0034	1.23	3.38	2.49	26.4	.0075	1.7	1,300
38	" tar	P	.0025	.89	4.09	2.62	35.9	.0963	34.67	1,050
39	Kieselguhr	K	.0018	.64	2.48	1.03	58.0	.0957	34.45	...
40	Graphite	QR-204/54	.024	8.64	2.42	1.79	26.0	0	0	...
41	"	QR-204/68	.025	9.0	...	...	...	...	...	...
42	Stone ware	GT-5	.0032	1.15	2.56	1.96	23.4	.0022	.80	1,050
43	"	GT-9	.0049	1.78	2.36	2.13	10.1	0	0	1,300
44	"	G-44-5	.0031	1.10	...	...	...	...	...	1,050
45	"	G-44-9	.0048	1.72	2.42	2.18	9.59	...	...	1,300
46	"	G-152-5	.0034	1.22	2.41	1.93	19.05	...	...	1,050
47	"	G-152-9	.0040	1.44	...	...	...	...	...	1,300
48	"	G-189-5	.0038	1.37	2.57	1.91	25.5	.0047	1.68	...
49	Porcelain	PN	.0046	1.66	...	...	...	...	...	1,400
50	"	PD	.0043	1.55	...	...	...	...	...	1,400
51	Sèvres stoneware	67	.0045	1.61	...	...	...	...	...	1,300
52	Building brick	TCB-5	.0033	1.20	2.48	1.98	19.9	...	...	1,050
53	"	TCP	.0037	1.34	2.56	1.90	25.7	.0015	.53	1,050
54	"	T-2-5	.0035	1.25	...	...	...	...	...	1,050
55	"	T-2-5/40	.0034	1.22	...	...	...	...	...	1,050
56	"	T-3-5	.0028	1.01	2.54	1.95	23.0	.0021	.74	1,050
57	"	T-3-5/42	.0035	1.26	...	...	...	...	...	1,050
58	Vallauris clay	V-48	.0028	1.03	...	...	...	...	...	...
59	"	V-51	.0024	.86	2.55	1.71	32.9	.178	64.1	...
60	"	V-57	.0023	.83	...	...	...	...	...	...
61	Light c'ay	L/52	.0024	.86	2.60	1.41	45.7	.0164	5.90	...
		4/58	.0023	.84	...	...	...	...	...	...

*Green. †Burned for 60 days.

This method is only available for non-vitrified materials, in which the air bubbles are not completely enclosed in the glass-like material, as is the case with stonewares and porcelains.

The results obtained are given in Table 11.

Table 11. Density and Porosity.

NATURE OF BRICK	Marks	DENSITY		POROSITY	
		True δ	Apparent δ	% in Weight	% in Volume
Fire brick.....	RA-5-31	2.61	1.81	17.08	30.85
" ".....	RA-9-30	2.5	1.9	12.1	24.1
" ".....	RB-5-20	2.59	1.81	16.12	29.44
" ".....	RB-9-24	2.55	1.78	16.0	30.2
Checker brick.....	2—	2.65	1.91	14.5	27.8
Gas retort.....	20	2.58	1.87	14.5	27.3
Bauxite.....	Bx-5-16	3.22	1.89	22.0	41.49
" ".....	Bx-9-15	3.12	1.92	20.0	38.4
Silica.....	S-5-14	2.75	1.58	26.98	42.58
" ".....	S-9-13	2.62	1.50	28.63	42.90
Silica burned at 1400°.....	S-9-13	2.57	1.50	27.59	41.52
Magnesia.....	M-5-12	3.07	2.0	17.61	35.12
" ".....	M-9-61	3.39	2.0	20.64	41.0
Euboea magnesite.....	M-53	3.59	2.40	13.15	31.52
Euboea, mag. and clay V.....	MV-56	3.39	2.02	19.93	40.32
Glass pot.....	P-2-22	2.65	1.86	15.95	29.69
" ".....	P-3-21	2.50	1.95	11.2	21.9
" ".....	B-4-43	2.52	1.77	16.57	29.44
" ".....	B-5-27	2.53	1.71	17.0	30.4
Carborundum.....	C-5-17	3.02	1.95	17.0	35.2
" ".....	C-9-18	2.83	1.96	15.58	30.6
Graphite.....	P-9-10	2.37	1.7	16.7	28.4
" ".....	QR-54/204	2.42	1.79	14.52	25.97
Chromite.....	Ch-2-59	4.06	3.19	6.7	21.3
" ".....	Ch-2-26	4.03	2.98	8.75	26.09
" ".....	FA-5-62	3.38	2.31	13.74	31.7
" ".....	FA-9-63	3.38	2.49	10.6	26.42
" ".....	P-9-64	4.09	2.62	13.0	35.9
Kieselguhr.....	K-39	2.48	1.03	57.0	58.0
Stoneware.....	G-T-5-37	2.56	1.96	11.95	23.38
" ".....	GT-9-29	2.36	2.13	4.75	10.10
" ".....	G-44-9-25	2.42	2.18	4.39	9.59
" ".....	G-189/5-35	2.57	1.92	13.29	25.46
White terra cotta.....	TCB-5	2.48	1.98	10.05	19.94
" ".....	TCP-6	2.56	1.90	13.53	25.71
Red terra cotta.....	T-3-7	2.54	1.95	11.76	22.99
Vallauris clay.....	V-51	2.55	1.71	19.23	32.92
" ".....	L-53	3.50	2.40	13.15	31.52

It is interesting to note the variation of density that takes place during burning and especially when in use in furnaces.

The density of silica brick burned at 1050 deg. was 2.75; it became 2.62 for the brick burned at 1300 deg., and 2.57 after long heating at 1400 deg. This increase in volume is due to the allotropic transformation of the quartz in tridymite. The change in density is accompanied by only a slight change in porosity.

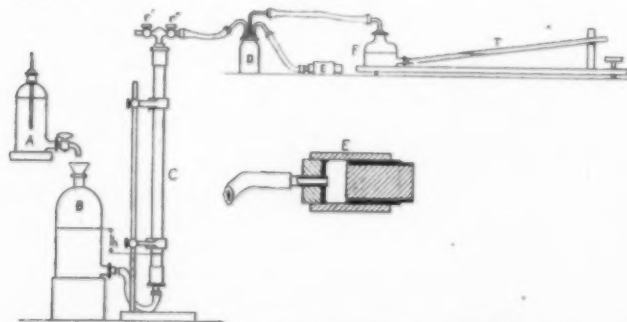


FIG. 7.—APPARATUS FOR DETERMINING PERMEABILITY.

With the pure magnesite brick M, on the contrary, the change in density is accompanied by a marked change in porosity; the density 3.07 of the magnesite brick burned at 1050 deg. becomes 3.39 when burned at 1300 deg. The fragment of a magnesite brick from the Thiel lime kilns was shown to have this same density; the magnesite was distinctly crystallized, almost transparent, and very dense; its porosity was very low, 8.7 per cent against 41 per cent of the brick M-9. This change in the magnesite is doubtless an allotropic one, as yet not well understood. It will be shown further on that these allotropic transformations are accompanied by enormous changes in gas permeability.

It is of interest to remark that the graphite bricks with a rather high porosity, 25 to 28 per cent, are practically impermeable to gases. In this instance, as is the case with pure clays, the pores must be exceedingly minute.

Gas Permeability.

The lack of homogeneity in the plates, the presence of fissures, often invisible to the naked eye, rendered difficult the permeability tests. As will be seen, the permeability varies in a marked degree when the other physical properties vary but slightly; this is to be explained by the relatively large changes in the dimensions of the capillary pores due to the allotropic transformations of the clay, silica, magnesite, etc., which changes are usually followed by increase or decrease in the density.

The gas permeability is not a constant for a given specimen,

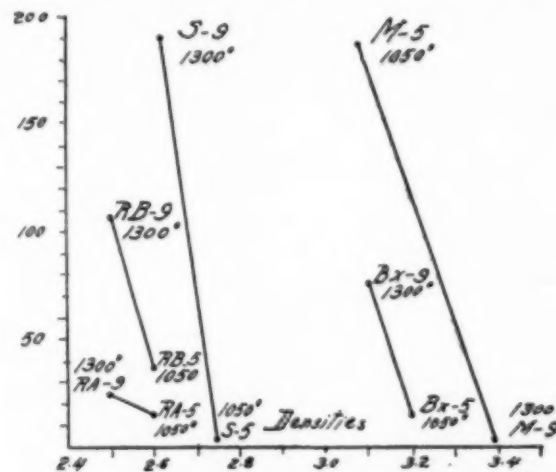


FIG. 8.—PERMEABILITY AS FUNCTION OF DENSITY.

as it varies with the different axes. The permeability in an axis normal to the face of the plate is different from that in an axis parallel to the surface.

This phenomenon prevented the use of a very simple measuring method which consisted in the determination of the volume of air passing in a given time, through the thickness of the plate, when a known gas pressure is maintained in a tube applied to the surface of the brick under test.

By comparing the figures so obtained with the results of the determination made on small cylinders cut out of the same plates and enclosed in a glass tube, it was found that the ratio between the two sets of figures was so large as to exclude the influence of experimental errors.

Permeability to Gases.

MATERIAL	Permeability Lit. Sec.	Ratio
Silica (S-9), directly.....	.109	
" " in the cylinder.....	.302	3.4
Bauxite Bx-9, directly.....	.044	
" " in the cylinder.....	.0127	3.5
Bauxite Bx-5, directly.....	.0054	
" " in the cylinder.....	.0018	3.1
Fire brick RB-5, directly.....	.016	
" " in the cylinder.....	.0063	2.5
" " RA-5, directly.....	.0069	
" " in the cylinder.....	.0025	2.8
Magnesite M-53, directly.....	.0016	
" " in the cylinder.....	.0009	1.7

In the above table are given the results obtained by the two methods.

It was thus necessary to select the second method, though it necessitated a long and tedious preparation of the specimens. Cylinders were cut about 40 mm in diameter and of the thickness of the plates; a coating of paraffin was applied to the cylindrical surface, leaving exposed the two parallel faces. It was necessary to avoid all air bubbles between the specimen and the paraffin and to prevent at the same time any penetration of the paraffin in the pores of the cylinder.

This was best attained by rubbing the cold cylinders with a piece of paraffin just about to solidify; in this manner the paraffin makes a good coating, at the same time freezing immediately upon contact with the cold brick.

Thus prepared, the cylinder is introduced into a glass tube,

the joint between the glass and the cylinder being carefully luted with paraffin to avoid any leaks when gas pressure is applied in the tube, the other extremity being closed by a rubber cork provided with a small glass tube.

In Fig. 7 is shown the apparatus used with bricks of small permeability.

The cylinder *C*, 55 mm in diameter and of about 2 liters capacity, graduated in cubic centimeters, served to measure the volume of air passing through the brick "G" in a given time.

The cylinder *C* was connected by its lower extremity with a bottle *B*, which received the water flowing from a Mariotte bottle *A*; the upper extremity of *C*, provided with two cocks

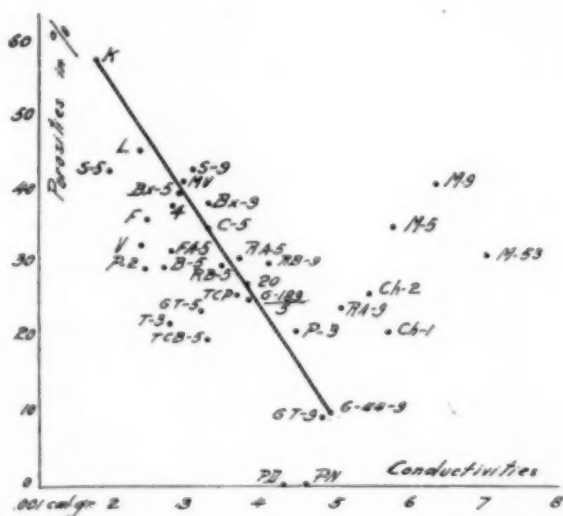


FIG. 9.—CONDUCTIVITY AND POROSITY.

r_1 , r_2 , was connected with a flask D , which in turn was in communication with the tube E , holding the brick cylinder under test G , and with a manometer F , the tube of which T was inclined to a slope of 1 in 10.

For bricks of great permeability the tube C was replaced by a large gasometer graduated in liters.

Tests were conducted as follows:

The bottle B is lowered with cock r' open, thus filling C with air; r' is then closed and B raised to a height h , this giving a pressure p in the cylinder E ; the pressure is measured by the manometer F ; as the air passes through E , the head h decreases; to maintain it constant water is allowed to flow from the Mariotte bottle A . When a state of equilibrium has been established, the level of the water in the manometer T remaining constant, readings are taken of the water levels in C .

To detect any leaks through the paraffin coatings, the tests were repeated at least twice. For most of the bricks additional determinations were made by reversing the direction of the gas flow through the cylinders *G*, by turning them end for end in the glass holder *E*. All tests were repeated until concordant figures were secured.

The coefficient of permeability v is the quantity of air in cubic centimeters passing under a head of 1 cm of water in one second through a cylinder of 1 sq. cm cross-section and 1 cm in height.

For practical applications, the coefficient v may be better expressed by the number of liters passing in one hour through a surface of 1 sq. m 1 meter thick; this new coefficient is V .

Let g be the quantity of air in liters passing t minutes under the pressure $p-p_0$ (p_0 being the height of water in the manometer tube T corresponding to the atmospheric pressure) through the cylinder of cross-section s and length l .

The coefficient of permeability will then be

$$v = \frac{1000 \text{ gl}}{t(p - p_0) \times 60 \text{ S}} = \frac{16.667 \text{ gl}}{t(p - p_0) \text{ S}}$$

In Table III are given the coefficients of permeability, v and V .

The coefficients of permeability are very different in the various bricks, and even in the same type of brick according to the temperature of burning, the size of the grains, etc.

For instance, the silica bricks burned at 1050 deg. have a permeability of 3.3 liters per hour, 192 liters when burned at 1300 deg., 241 liters when burned at 1400 deg.

A like change is seen in the fire bricks RB and RA, as well as with the bauxite bricks. This phenomenon is well shown in Fig. 8, giving the permeability in function of the true density before and after burning; the increase in the density is always followed by a decrease in the permeability. With the magnesia bricks, as the density increases with the temperature, so does the permeability, the same law being thus followed. Further, in the case of bricks where no increase of density results from the increase in temperature, there is also no appreciable increase in permeability.

Herr Simonis¹ reviewing the results that I recently published in the Bulletin de la Société d'Encouragement and the figures given by Nousselt² arrived at the following conclusion:

"The heat conductivity of clay refractories is that of the air enclosed in the pores and not that of the clay material itself."

The diagram of Fig. 9, in which the abscissas represent the mean conductivity of the different bricks, and the ordinates the corresponding porosity expressed in volume percentages, appears to confirm the Simonis rule.

From Fig. 10, which is diagram of Fig. 9 drawn on a smaller scale to include all the collected data, it will be noticed that the only bricks which do not follow the law are the chromite, magnesia, carborundum, and graphite bricks, which are not clay refractories. To the left of the straight line passing through the characteristic points of the diagram of Fig. 9 (K, B-5, G-189-5, G-44-9) are only the bricks of high heat conductivity (chromite, magnesia, carborundum, graphite).

Doubtless the porosity is not the only property that affects the heat conductivity of refractory materials. It may be added a priori that the degree of isolation of the air bubbles enclosed between the particles of the bricks, i.e., their gas permeability, must also affect the conductivity.

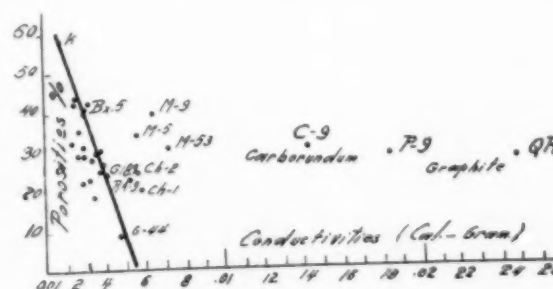


FIG. 10.—CONDUCTIVITY AND POROSITY.

Permeability and Conductivity.

MATERIAL	Porosity %	Permeability in L. per hr. per sq. m.	Conductivity kg.-cal. per Hr. per sq. m.
Glass pot, P-2.....	30.0	.30	.89
" B-5.....	30.4	1.02	.96
Fire brick, RB-5.....	29.44	37.84	1.25
" " KA-5.....	30.85	14.72	1.32
" " RB-9.....	30.2	106.2	1.50

Taking bricks of a like porosity, for example, 30 per cent, Fig. 9 (P-2, B-5, RB-5, RA-5, RB-9), it is seen that the permeability increases with the conductivity.

The silica bricks with an equal porosity, 42 per cent, Fig. 9, appear to justify the same conclusion.

¹M. Simonis Beitrag zur Bestimmung der Wärmeleitfähigkeit von Schamotteziegeln Sprechsaal, Jahrgang XXXI, No. 40, 1908.

²Nousselt, 2. des Vereines Deutsch, Ingen, No. 23, 1898, and Tech. Mittheilungen. Nürnberg, Juli, 1906.

Permeability and Conductivity.

MATERIAL	Porosity %	Permeability in L. per Hr. per sq. m.	Conductivity kg.-cal. per Hr. per sq. m.
Silica brick, S5.....	42.58	3.32	.71
S9.....	42.90	192.9	1.12

Thus the conductivity increases when the enclosed air bubbles have the greatest maximum mobility; i.e., when the permeability is also greatest.

Some Physical Characteristics of Iron Alloys.

By CHARLES F. BURGESS AND JAMES ASTON.

In connection with an investigation¹ of the properties of electrolytic iron and its alloys having a carbon content so low as to warrant their being considered as practically carbon free, the forgeability, welding and machining of these metals were tested and the results are summarized herein.

The basis of all the alloys is iron of a high degree of purity, obtained by a double electrolytic refining of commercial Swedish iron. This electrodeposited material has an impurity content of about 0.03 per cent, the iron by difference being 99.97 per cent. The desired amounts of this pure iron are weighed out, together with the proper percentages of the alloying elements, and placed in a covered magnesia-lined graphite crucible, which latter is buried in an electric furnace of the resistor type. After melting, an ingot is obtained of about 500 grams (1 lb.) in weight. Under these conditions of melting there is no agitation of the charge, nor is there any addition of the desired elements to the molten charge, and the resultant alloy is obtained entirely by diffusion of the elements, after being together brought to fusion from the cold state.

The ingots are heated in a forge fire and drawn out under a steam hammer into a rough bar from $\frac{1}{2}$ in. to $\frac{3}{4}$ in. in diameter and about 18 in. to 20 in. long, and from this the necessary test samples are obtained by turning or grinding.

The results of the above method of preparing the alloys are indicated by the agreement between the percentages of the alloying elements as added and as obtained by analysis of the turnings after melting and forging. Analyses of about 100 of the binary alloys show that very generally there is but little variation between the added and actual percentages, particularly among those elements which are most commonly used in alloy steels. In the nickel, copper and cobalt series this agreement is strikingly close; with tungsten, molybdenum, chromium, manganese and silicon it is reasonably so. In the last mentioned series, one alloy with an added content of 7 per cent Si showed on analysis only 3.33 per cent, but this variation is exceptional and not to be generally expected. Silver, selenium, aluminum and lead do not alloy at all in the proportions added; for silver this is particularly true, since the maximum percentage as analyzed is 0.697 per cent, while a maximum of 10 per cent was added. The most striking and unexpected instances are noted in the tin and arsenic series. Both of these metals vaporize at temperatures far below the melting point of iron. And yet we find very considerable amounts of the elements remaining in the alloy. For tin, the order of the series does not change, and about half of the added content remains; for arsenic, the agreement is very close up to an actual percentage of about 4, which seems to be the saturation limit, since for the alloys of 6 per cent and 10 per cent of added As the content has fallen to the above percentage.

Random analyses for carbon show small percentages, varying somewhat in the different alloys. Investigation leads us to believe that the greater part is due to the absorption of the carbon set free in the equilibrium reaction of iron upon the carbon monoxide gas of the furnace ($\text{Fe} + \text{CO} = \text{FeO} + \text{C}$). The amount of this carbon and other impurities is so small,

however, that whatever properties are observed in the alloys may be said to be due to the addition of the various elements.

The notes given in the appended tables are the results of observations during the working of the ingots into test bars, and are qualitative, rather than quantitative. For the forging, we are indebted to Mr. Lottes, instructor in forge practice at the University, who has given a great deal of attention to the working of alloy steels. In case trouble was encountered in working at normal forging temperatures, different heats were tried to determine the best conditions. Upon indications of cracking or crumbling efforts were made to weld the bar, and the result noted. In general the welding tests were made upon a Thomson electric welder. The nature of the weld was determined by grinding the juncture and by testing with the hands. In many cases, no doubt, as Hadfield has aptly said, "the pieces may be stuck together and not truly welded, as a tensile test would soon show."

The machining tests include the nature of the material in the lathe, or its general hardness as noted in sawing and filing. All are in the condition resulting from forging, and without any annealing or other heat treatment.

In the tables the forging, welding and machining characteristics are arranged in three columns, and the various alloys are grouped alphabetically under the head of the predominating element. The observations were usually made and noted on each bar, but the results are given as a summary of the general effect of the alloying additions. The table is sufficiently explanatory to obviate the necessity of much discussion.

The forgeability of the various alloys does not differ greatly from that of similar commercial materials, qualitatively speaking; quantitatively, the effect of the impurities, especially the carbon content, will no doubt change the limiting ranges. Likewise, while carbon is conducive to the hardening by quenching of many of the alloys, and while it has its quantitative effect upon all, it will be noted that chromium, manganese, molybdenum, nickel and tungsten promote self-hardening properties, even when carbon is absent. In fact, many of these last named alloys make satisfactory lathe tools, either in their air hardened condition or after quenching.

In addition to the materials listed in the tables, a large number of alloys were made up, of which the compositions and the results obtained are too diversified to enable systematic deductions to be drawn. These were very largely combinations of iron with several of the five elements mentioned above, and which are those generally found in self-hardening steels. They were very generally so hard as to require grinding into test bars, and practically all were forgeable with care in selecting the proper temperature, the precautions necessary being those usually taken in the working of high-speed steels.

Physical Characteristics of Iron Alloys.

Forging.	Welding.	Machining.
Electrolytic Iron. Easy. Brittle as deposited. Loses brittleness on heating to redness. Fused material can be worked cold. Forges well at all heats.	Easy in forge and also in electric welder.	Somewhat hard as deposited; can be easily machined, but is brittle. Like soft iron after heating or fusion.
Aluminum. (2-3%) forged well at forging heat.	Did not weld in electric welder.	Al-Fe bars trifle harder than iron but turn easily.
(2.3%) forges at welding heat.	Did not weld in forge. Welds in electric welder. (2%) welds in electric welder.	
Antimony. Alloys up to 10% made, but only that with 1% would forge. Rest crumbled.		No trouble in machining the alloy of 1% added Sb.
Arsenic. Alloys up to 4%. Forge well at normal heats. High As requires higher temperatures and must not be worked at dull heats. Odor upon slight heating.	All weld in electric welder.	Soft. Brittle at higher As content. Turns easily.
		Marked odor even upon grinding bars.

¹This investigation is being conducted in the Chemical Engineering Laboratories of the University of Wisconsin largely through a grant of the Carnegie Institution of Washington.

Forging.	Welding.	Machining.	Forging.	Welding.	Machining.
<p>Bismuth. Forged without difficulty, but Bi present in not more than trace, even though 10% added to charge.</p> <p>Cadmium. But one alloy made of 5% added content. Forged easily. Analysis showed no Cd present.</p> <p>Chromium. Alloys up to 22% added Cr made. Analysis agrees with added %. Forge easily at all heats, and can be worked at low temperatures. At Cr content of 10% they forge somewhat more difficultly.</p> <p>Many CrSi alloys made, and in general forge well. Must be treated like self-hardening steels. They forge in all % Cr up to 20 or 30 and Si to several %. Forging becomes more difficult where Si reaches 3 or 4%. Temperatures used, a forging or yellow heat.</p> <p>Further addition of Mo, Ni, or Mn to CrSi does not materially affect forgeability.</p> <p>Cr and Ni in all % up to 10 of each work well.</p> <p>Addition of 0.3 to 0.5% V to alloys with up to 10% Cr did not affect forgeability.</p> <p>NiCr alloys up to 10% of each in alloy, together with 1 or 2% Si or up to 1% C, or a total of C+V=1% forged well at normal temperatures.</p> <p>Most of the failures in forging are among Cr alloys + some other element. But in other cases alloys of like composition forged.</p> <p>Cobalt. Alloys up to 6% added and analyzed amounts agreed. Forged without difficulty at normal forging temperatures.</p> <p>Copper. Wide range of alloys of all compositions. Analysis agreed with added.</p> <p>Up to 2% forge well at low heats.</p> <p>2 to 7% will not forge at low heat and poorly at white heat.</p> <p>7% to 75—80% will not forge.</p> <p>80 to 100% forge at fair red heat but not at normal forging heat for iron.</p> <p>In earlier work, alloys above 5% could not be worked. In later tests, many alloys of 5 to 10% were tried at all heats. With care and a high heat (welding) a 7% bar can be forged (or even an 8% rarely).</p> <p>80% Cu alloy forges somewhat cold and works well at dull red.</p>	<p>Welded in electric machine.</p> <p>But one Cr bar (1%) tested did not weld in electric machine.</p> <p>Many CrSi alloys did not weld in electric welder, but many others of about the same composition did. Evidently care needed to get right conditions.</p> <p>Cr + W + Si and Cr + Mo + Mn + Si did not weld in electric welder.</p> <p>Cr + Ni in all % up to 10 of each will weld in forging.</p> <p>Low percentages (below 5) will weld in forging.</p> <p>Also some bars of 7% welded in forge heating.</p> <p>Up to 7% welded in electric welder.</p> <p>High % not welded.</p>	<p>Soft and easily machined. Bi content doubtful.</p> <p>Soft and turned like steel.</p> <p>The Cr and CrSi are in general hard, and are not put in soft condition by any annealing process.</p> <p>Cr V alloys hard.</p> <p>These alloys were hard.</p> <p>Soft, except for 6% Co, which is slightly harder. But all can be machined in lathe.</p> <p>Lower % works easily.</p> <p>Somewhat harder with these % but work without difficulty. Hardness increases with increase of Cu. At 7% the alloy is very hard.</p> <p>High Cu alloys work like copper. Drag on tool.</p>	<p>A 75% Cu smashed at dull red.</p> <p>Alloys of 5 Cu 1 Al 2 Cu 1/2% forged easily at high heat.</p> <p>But a 4 1/2 Cu 4 1/2 Al and a 10 Cu 4 Al smashed in forging. Likewise an 89 Cu 4 Al.</p> <p>Two alloys of 2 As 3 Cu and 4 As 3 Cu forged at normal temperatures. The former checked badly and the latter broke in swage.</p> <p>The CuSi alloys worked with difficulty if Cu and Si rise to appreciable amounts. When total of Cu + Si exceeds 7% they forge with difficulty. One reported forged with 6.67 Cu and 6.67 Si, but no analysis to confirm these amounts.</p> <p>At high Cu % (90 and above) the alloys do not forge if Si of 1% is present.</p> <p>Lead. But one alloy of 3% added, but only 0.06% analysis. Worked at forging and welding heat cracked and finally broke in swage.</p> <p>Manganese. Several alloys of manganese content up to 12% made. Analysis checked reasonably well. All forged without difficulty at forging and welding heats.</p> <p>Molybdenum. Alloys up to 15% made. Analysis in agreement. Forges well at all heats. Generally worked at forging and low forging heats.</p> <p>Addition of 0.6 to 1.2 C to 8 to 10% Mo will forge with care. Low forging heat. An ingot of 15% Mo 1 C did not forge.</p> <p>An ingot of 10 Mo 2 Si forged at weld heat while one of 10 Mo 4 Si did not.</p> <p>Alloys of 5 to 10 Mo and 10 Cr forged at normal heat. Addition of 0.5C or V to this requires care in heating and working.</p> <p>A 10 Mo 2 Ni forged well.</p> <p>Various alloys of Mo up to 10% with additions of 1 or 2% Mn or about 0.5 V or about this % V with up to 0.6 C forged well at normal heats.</p> <p>Nickel. All percentages made from 0 to 100 Ni. Analysis checked closely. Lower percentages forge same as iron at normal forging temperature. Ingots sound, but usually heads on top, probably due to extrusion of last fluid material by contraction on cooling. Alloys of 25, 26, 28, 35, 50 and 75% Ni were forged without especial difficulty, although in an earlier instance a 75% smashed at low and high heat. Could not forge a 100% Ni. In</p>	<p>Also welded in forging.</p> <p>Several bars of 1 to 3% Cu and 0.5 to 1 Al welded in elec. welder.</p> <p>All of CuAs bars welded in elec. welder. 3 to 5 Cu and 1 to 4 As.</p> <p>1 bar 0.5 Cu and 0.25 Si did not weld in elec. welder. One of 3 Cu + 0.5 Si did.</p> <p>CuSi alloys work easily like wrought iron.</p> <p>High Cu with Al or Si worked like Cu.</p> <p>This one bar did not weld in electric welder.</p> <p>Bars of 0.50 and 4% Mn welded in electric machine. 12% bar did not weld.</p> <p>Became hard at about 4%. 1 and 2% alloys machined with air hardening lathe tools. Others ground.</p> <p>Hard, becoming very hard at 5% and upward.</p> <p>Hard.</p> <p>Also welds.</p> <p>All hard.</p> <p>Hard.</p>	<p>Work easily in lathe.</p> <p>4 As 3 Cu brittle and hard. Also 2 As 3 Cu hard. Works easily in lathe.</p>

a 28-in. x 72-in. board of black oiled slate, providing switches and plug receptacles for the control of all current which is used for any purpose within this room. The cells are connected in series groups of three each, the outside terminals of each group having double receptacles. This arrangement enables the operator to connect his cells with any number of groups in multiple, thus giving greater latitude in the selection of voltage and current strength than is possible with the usual series connections.

The 110-volt charging current enters the board through a switch which can be connected by plug connectors with any cell or combination of cells, and a slide-wire rheostat on the back of the board makes it possible to charge any number of cells at a time. The cells are protected during charging by an under-load circuit-breaker, and also during both charge and discharge by a fuse panel which is placed on the back of the

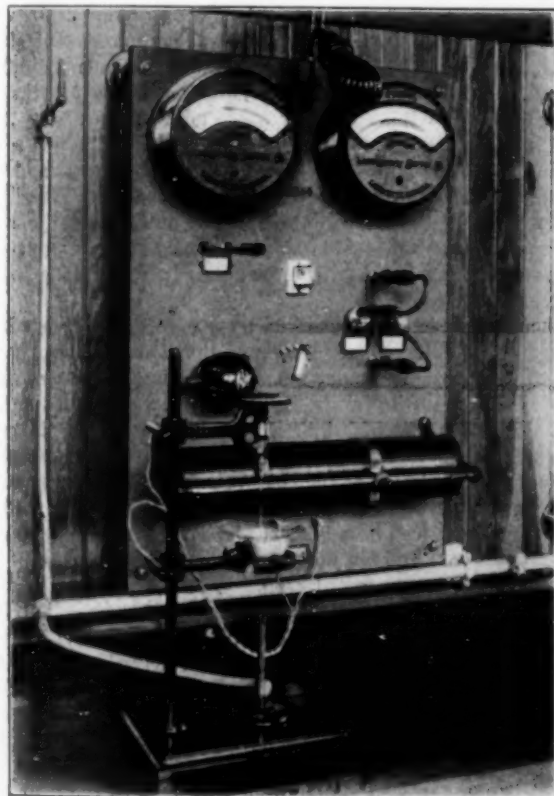


FIG. 1.—A SINGLE DESK PANEL, SHOWING ELECTROLYZING STAND AND ROTATOR.

board. An ammeter with a range of 20 amp and a double scale voltmeter, with ranges of 150 volts and 15 volts, are provided for proper control of the charging process. The 15-volt scale is used for testing the voltage of the cells when they are not in use.

A switch on the distributing board controls the 110-volt alternating current which is used for the lights and motors. Finally, on this board are the terminals for all of the desks, so that any operator may connect with his desk any of the cells not then in use, and in almost any combination. It will be seen from this brief description that the connections on this board make the different cells and desks practically independent of each other; for instance, a part of the cells may be charging while the remainder may be distributed to the various desks as wanted.

At each working desk is a 24-in. x 36-in. slate panel which carries all of the apparatus that will be needed by the analyst, making each board an independent working unit. The voltmeter and ammeter on each board are double-scale instruments with ranges of 2 volts and 20 volts and amperes, respectively.

The multiplier for the voltmeter is controlled by a small knife switch, and the shunts for the ammeter are joined to plug receptacles. These measuring instruments are of such an unusual character as to deserve special mention.

Instruments which could be mounted in the usual manner on switchboards, but which would possess all of the features which make the superior accuracy of the best portable instruments, were desired for this purpose. The Central Laboratory Supply Company designed a special instrument embodying

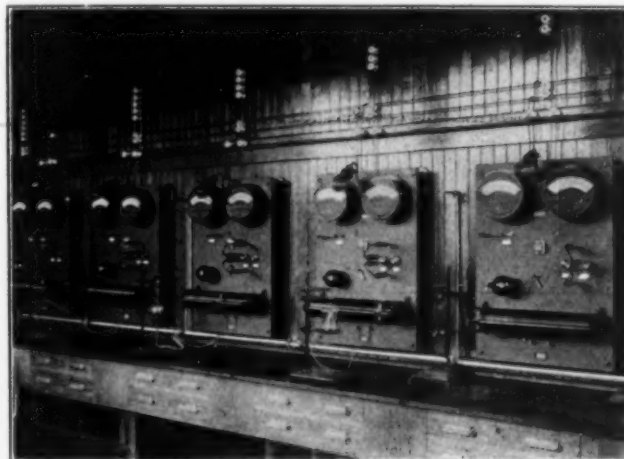


FIG. 2.—GROUP OF FIVE DESK PANELS.

these features. The case is of the switchboard type; the movement is of high grade and made with great care. The pointer is thin and is provided with a mirror background, making it possible to read without parallax. The scale is specially drawn with all of the care used in making the scales of high-grade portable instruments and the calibration has been performed with similar regard for accuracy. The whole case is sealed to make it air tight and is enameled in polished black, which not only gives it a handsome appearance, but also thoroughly protects the movement from the attack of acid fumes.

The current to each desk panel is controlled by a slide-wire taper rheostat of special design. The slide-wire type of rheo-

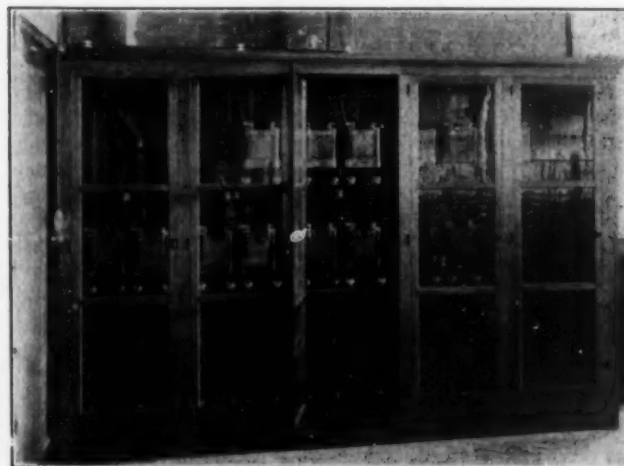


FIG. 3.—STORAGE BATTERY CASE.

stat was selected for this purpose because it provides in a small space a large amount of resistance in a large number of steps, conditions which, in a rheostat of the radial type, would require an instrument of such size as to make it decidedly cumbersome. These rheostats are wound to give a total resistance of 130 ohms, in 254 steps. The carrying capacity of the first step is 1.3 amp and that of the last step 25 amp, on continuous work.

For working with rotating electrodes 1/30-hp, alternating-current, series motors of the commutator type are mounted on the board and are controlled by a switch and 5-step rheostat. Induction motors are not used, because it is desirable to make variation in speed possible. These motors have a maximum speed of 2200 r.p.m. on 110 volts and are provided with three pulleys of different sizes.

In many laboratories it is the practice to mount the motor directly on the electrolyzing stand, thus avoiding all belting and making possible direct connection with the rotating electrode. On the other hand, the application of a small belt is a simple operation and not only very much decreases the vibration of

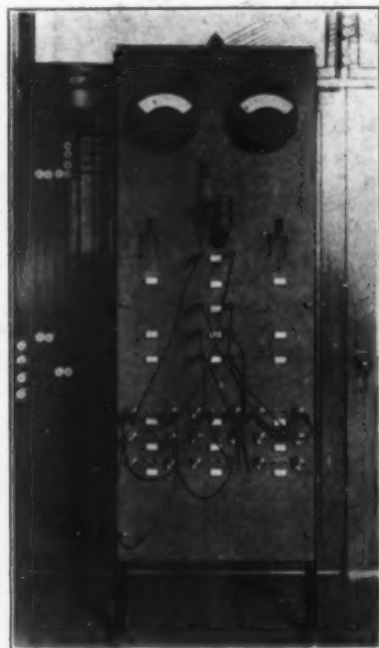


FIG. 4.—DISTRIBUTING SWITCHBOARD.

the stand, and consequently the danger of dust particles falling into the bath, but also removes the motor from the region of the bath, which in many cases contains acids and which is frequently hot. Corrosion of the motor parts is in this way largely prevented.

The stand for holding the electrodes is made according to our own specifications. It is of iron, is quite heavy, to prevent vibration, and is fitted with rubber feet. Every portion of the base and vertical rod is heavily enameled and the electrode supports are clamped to the rod by means of heavy thumb screws, but in such a manner that the screw does not come into contact with the rod, so that the enamel is not injured by the grip. Each clamp is insulated from the rod by a fiber bushing and each carries a binding post. There is no glass about the stand, perfect insulation of the electrode clamps being secured by the fiber bushings. The supporting ring for a dish cathode has three brass screw contacts, which are adjustable for dishes of different sizes. Finally, for cone and spiral, or similar stationary electrodes, simpler clamps are provided to take the place of the rotator. The rotator, which carries three pulleys of different sizes, is a vertical shaft, the lower end of which carries a universal chuck, electrical contact being insured by a brass brush.

Practically every metal part of every piece of apparatus in the laboratory is protected against corrosion by heavy enamel, the only exceptions being the plug receptacles and the switches. The outward appearance of the whole installation is good and a thorough test has demonstrated the intrinsic merit of every part of it. It is believed that in thoroughness of design and in scientific care in manufacture the equipment of this laboratory is excelled by few in this country.

The Testing of Galvanized and Other Zinc-Coated Metals.*

BY DR. WM. H. WALKER.

Three methods are now commercially used to coat iron with zinc. The oldest and for many years the only commercial method is the "hot-galvanizing" process, in which the iron article is simply dipped into a bath of molten zinc. The second is the "wet" or "cold-galvanizing" process, in which zinc is plated on the iron article by electrolysis from a solution of a suitable zinc salt. The third is the "sherardizing" process of Sherard Cowper-Coles, in which the iron article is heated in a closed chamber in the presence of finely divided metallic zinc and zinc oxide. (See our Vol. VI, page 189.)

Preece Test.—Although there is a marked difference in appearance and in structure between these three kinds of zinc-coated iron, only one method of testing them has been used, namely, the "Preece" or copper-sulphate immersion test.

As standardized by the American Telegraph & Telephone Company this test is essentially as follows: A standard solution of copper sulphate is prepared by agitating a nearly saturated solution of this salt with copper oxide until it is perfectly neutral. It is then diluted to 1.186 sp. gr. at 65° Fahr. When a rod of zinc and one of iron are placed in this solution the metals pass into solution as soluble sulphates, an equivalent weight of copper being at the same time deposited on the metallic rods. The copper deposited on the zinc surface is black, spongy and easily removed, while on the iron it is dense and of a bright color.

When this reaction is used in testing galvanized iron it is assumed that the speed of solution of the zinc is a direct function of the time of immersion, and by the number of one-minute immersions necessary to dissolve the zinc from the iron and to deposit a film of bright copper thereon, the thickness of the zinc can be estimated. It will be seen that this method measures the thickness of the coating only at its thinnest point, and that the assumption is made that no bright copper will be formed until the iron base is reached. To appreciate the limitations of this test, it is but necessary to note the structure of the three classes of zinc-coated iron.

A polished oblique section of ordinary hot-galvanized iron etched with iodine reveals three distinct layers. First, a coating of zinc, which varies in thickness in accordance with the temperature of the zinc and the amount of squeezing or wiping applied to the article before the zinc solidifies; second, a distinct layer of a zinc-iron alloy, termed alloy B, which varies in thickness with the temperature of the zinc bath and the length of time the iron was subjected to it; third, the iron base itself. Between the zinc and alloy B there is generally a second alloy, alloy A, which is a thin, discontinuous layer, richer in zinc than alloy B, and between the iron and alloy B is a third alloy, relatively unimportant, which is very rich in iron, alloy C.

The structure of wet-galvanized iron is comparatively simple, the layer being practically pure zinc.

Sherardized iron, on the other hand, presents a relatively complex structure. The metallic zinc penetrates the iron, forming deep layers of the alloys B and C, and in place of alloy A there occurs a number of compounds, as yet unidentified. Upon the surface there is generally a layer of relatively pure zinc, although frequently the process is carried to the point where only a deep layer of alloys is formed. When examined under the microscope this alloy is seen to be covered with deep cracks or fissures as though the alloy in forming had contracted. It is thus apparent that in testing galvanized iron made by these different processes we are dealing with three very different materials.

Desiderata for a New Test for Determining Durability or Resistance to Corrosion.—It is the purpose of this paper to treat of zinc-coated iron with regard only to its durability or

*Abstract of a paper read at the 1909 Atlantic City meeting of the American Society for Testing Materials.

resistance to corrosion, and not to its tensile strength. From this standpoint a test should, if possible, indicate the following:

(1) The uniformity and thickness of the zinc coating; (2) the continuity of the coating with reference to pin holes; (3) the purity of the zinc, and (4) the toughness and ductility of the coating.

The corrosion of pure zinc in water is very slow. If, however, the zinc is in electrical contact with any material upon which the hydrogen can be liberated, the corrosion of the zinc is relatively rapid. The iron-zinc alloy *B*, and iron itself, are both surfaces on which this depolarization action can take place, and, hence, so long as neither the iron nor the alloy is exposed, other things being equal, the zinc coating will not corrode. The importance, therefore, of maintaining a uniform coating of metallic zinc upon the iron can be appreciated.

To determine whether the ratio of the time of immersion required to produce a bright copper surface was in reality a measure of the thickness of the zinc coating, samples of galvanized sheets were obtained and tested. The weight of zinc per square inch area was determined by dissolving the zinc from the sheets without attacking the iron-zinc alloy. This can readily be accomplished by heating the galvanized sample, together with a piece of metallic iron, in boiling caustic soda until the generation of the hydrogen ceases. As might be expected, the ratio between the time of immersion required to show the presence of bright adherent copper and the amount of zinc present per unit area depends upon the uniformity with which the coating of zinc is spread upon the iron base. In the case of 14 pieces of galvanized sheet iron, for example, the average ratio found was 23, while the greatest variation in either direction was but 20. This test, therefore, so far as indicating the uniformity of the coating and measuring the thickness of the zinc are concerned, is fairly satisfactory; but alloy *B* is always indicated as iron, and hence, when the test is applied to sherardized articles, very erroneous and misleading results may be obtained.

The presence of the channels or pin holes caused by the free iron surface coming in contact with the zinc and causing it to pass into solution cannot be detected by the copper-sulphate method, as these pin holes down through the zinc to the iron fill up with black, spongy copper and cover up the bright copper spot at the bottom.

The purity of the zinc cannot be determined, as the bright copper particles precipitated by this method are so small that they are lost in the mass of black, spongy copper.

Finally, the fourth factor, the toughness or the ductility of the coating, cannot be determined, due to the same tendency of the spongy copper to cover up the bright copper deposits, which indicate cracks extending down through the zinc coating to the alloy or iron underneath.

Test for Detecting Pin Holes and Cracks.—The relation between the presence of pin holes in the zinc surface and cracks due to a brittle coating and the durability of the structure as a whole has heretofore been studied, largely because no method of detecting these imperfections has been available. The following phenomenon serves as a basis for such a test. If a piece of zinc be placed in a strong solution of caustic soda heated to about 100° C. no action is noticeable. If now the zinc be touched with a piece of iron, hydrogen is liberated in great volume from the iron. Small cracks in the zinc coating may be easily detected in the same way.

Ordinary hot-galvanized ware is generally very free from imperfections of this kind, while wet-galvanized ware, on the other hand, is frequently very porous, generating hydrogen at numberless small points over its entire surface. Theoretically, the best electroplated surface should be that carrying the greatest weight of zinc per unit area, deposited at the slowest rate. That is, the lower the current density at the cathode in plating the less porous will be the deposited metal, and the thicker this dense deposit is the better protection will it be. A great many tests on electroplated zinc-coated iron were made, the samples

varying in both these particulars. In every case, those deposited most rapidly were the most porous, and the results showed that the time of plating was more important than the weight of zinc per unit area, although there was a minimum below which it was not safe to go.

Test for Determining the Combined Effect of Imperfections.—As the rapidity of hydrogen generation from zinc is a function of the presence of an alloy of zinc and iron, hence the more impure the zinc coating, the more impure will be its solution in acid. Accordingly, the impurity of the zinc, the presence of pin holes and cracks, and the thinness of coating are all factors which act in an accumulative way to increase the rate at which hydrogen is generated when the zinc surface is exposed to acid. This method has been developed by Mr. Charles L. Campbell in his thesis for the B.S. degree at the Massachusetts Institute of Technology, and found to give very concordant results. The apparatus employed may take any convenient form, it being but necessary to expose a known area of the zinc coating to a standard acid solution under uniform conditions and to measure the hydrogen generated per minute. In almost every case a sharp maximum is reached giving the resultant of all the different factors which make for rapid dissolution of the zinc. Thus, in a series of wet-galvanized sheets, those electroplated for 15 minutes reached a maximum of 7 cu. cm in three minutes; those plated for 30 minutes a maximum of 14 cu. cm in 10 minutes, while those plated for 45 minutes showed a rather poor maximum of 6 cu. cm in 30 minutes. In many samples of sherardized product there were two maxima on the curve showing the amount of hydrogen generated per minute. This indicates that there is first an action between the outside zinc coating and the iron-zinc alloy, and later a well defined action between the alloy and the iron.

Service tests with galvanized iron are of necessity very slow at best, and the relation of the above phenomenon to the real durability of the material can be determined only after a number of years. Something can, however, be learned by the study of ware which has already been exposed for sufficient time to determine its durability. Most of the material available for the purpose was in the form of **fence wire**; from a study of these the following conclusions are drawn:

First, thickness of coating. In every instance where a very durable fence was found, the coating of zinc proved to be relatively very thick. On the other hand, the wire fences which showed marked corrosion in from one to two years proved to have almost no zinc on the iron, the zinc color being due to a layer of alloy alone. It is doubtless true that the purity of the iron used in the wire itself plays an important part in determining the ultimate durability of a fence, yet in the opinion of the writer the thickness of the zinc coating calls for more immediate attention. The modern method of close mechanical wiping the wire as it emerges from the zinc-bath produces too often a wire covered not with zinc but only a thin layer of electro-negative iron-zinc alloy, which affords but little protection to the iron. To produce a wire with a liberal coating of zinc would, of course, cost more both on account of the extra zinc and on account of a somewhat smaller production per machine.

Second, purity of zinc. It is probably a necessary consequence of hot galvanizing that the zinc becomes somewhat contaminated with dissolved iron. It is apparent that this should be kept at a minimum in order that the coating should be of maximum durability.

Third, flexibility of the zinc coating. The important objection to placing a thick coating of zinc upon wire used for fencing is that such a coating cracks off when running through the machine. This objection applies only to those wires which are subjected to very sharp bends or turns. It is possible that by passing the zinc-coated wire through dies or under grooved rolls that the crystalline condition of the zinc could be destroyed and the flexibility and ductility materially increased.

To sum up the results of this paper:

1. The copper-sulphate immersion test is of value in determining the uniformity of coating and relatively the thickness of coating in hot and in wet-galvanizing products; but it is worthless in the case of sherardized products, and gives no idea of other important factors involved in the durability of the structure.

2. By immersing a galvanized product in hot, strong caustic soda, the presence of any unprotected iron may easily be detected, however small such area may be.

3. The weight of zinc per unit area apart from the zinc-iron alloy may be analytically determined by dissolving the zinc from the plate through treatment with hot caustic soda while in contact with metallic iron.

4. Theoretically, the rate at which hydrogen is evolved when the galvanized product is immersed in dilute acid should indicate its relative durability; inferior products should reach a maximum in a few minutes compared with a much longer time for better products.

5. In the very important matter of fencing wire, while the purity of the iron used is of consequence, a more immediate necessity is a heavier coating of zinc on the wire.

6. The flexibility of a zinc-coated wire may possibly be increased by mechanically working the wire in rolls or dies to destroy crystallization in the zinc coating.

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The Laws of Electrode Losses in Electric Furnaces.

BY CARL HERING.

There are two kinds of losses which must be considered in electrodes: first, the loss due to the conduction of heat by the electrode from the material or gases in the furnace to the outside, which may be termed the heat conduction loss, or simply the thermic loss, and, second, the loss due to the electrical resistance of the electrode, which may be termed the electrical loss or the C^2R loss. Both losses originate electrically and are, therefore, of equal commercial value in cents per kilowatt, and both leave as heat and are, therefore, thermic; but the above distinction is useful for differentiating between them. For a given length, if the cross-section increases, the heat loss increases while the electrical loss diminishes; while for a given cross-section the reverse is the case when the length is increased. Moreover, the thermal and the electrical conductivities of the particular material enter into the determination of these losses; and the total loss may be partly thermal and partly electrical, or entirely thermal or electrical, or even only a part of the C^2R energy. As these physical properties of the electrode material are an important factor, a comparison between two materials, like graphite and carbon, is evidently not a fair one unless each of the electrodes has its best proportions. The problem of finding the best conditions is, therefore, not a simple one.

The designer of a furnace is, therefore, required to know how these necessary parts of a furnace should be designed and proportioned so as to reduce the total loss inherent in them to the least possible amount; and, if there are any theoretically best proportions, how far is it practicable to approach them. Unless we know whether there are any such ideal proportions, and, if so, what they are, we are evidently unable to even approach them in designing a furnace.

The writer, therefore, concluded that the most satisfactory way to solve the problem is to make an analytical study of the subject in order to determine the laws which govern the best proportions. Having such laws, the designer can then determine how closely it is practicable to approach these ideals. As it appeared that no one had determined these laws, the writer some time ago undertook their deduction and found them to be as follows, and as they are absolute, under the assumed conditions, they may be properly termed the laws of electrode losses.

Laws of Electrode Losses.

a. The combined loss through the cold end of an electrode is equivalent to the sum of the loss by heat conduction alone (when there is no current) and half the C^2R loss.

b. This combined loss will be least when the loss by heat conduction alone is made equal to half the C^2R loss; the total loss will then be equal to the C^2R loss and no heat will be conducted from the interior of the furnace.

c. This minimum loss is dependent only on the material, current, and temperature, but not on the absolute dimensions; it merely fixes the relation of the cross-section to the length, but leaves a choice of either; hence

d. For economy of electrode material the length should be made as short as practical considerations permit.

e. For each material there is a definite minimum loss of electrode voltage which depends only on the temperature and is independent of the dimensions or the normal current for which the furnace is designed; hence,

f. The best possible electrode efficiency for any material may be determined from the total voltage of the furnace and this minimum voltage due to the material and the temperature, and is independent of the dimensions.

g. The heat gradient of the combined flow is equal to the sum of the heat gradients of the individual flows.

These laws are based on the following fundamental assumptions, any departures from which must be treated as correction factors: That the electrodes have a uniform cross-section throughout their whole length. That no heat leaves the electrode to the furnace walls or enters it from them; this is approximately true in most cases because the heat gradients are approximately the same in both, and there is contact resistance between them, which may be quite great. And that the temperature variation of the conductivities is approximately a straight-line proportion. Neither of the two latter conditions seems to be accurately true, but the differences are probably small in comparison with the best possible degree of accuracy with which the best proportions of furnaces can be predetermined or realized in practice. Hence, great accuracy is not essential. The matter of importance for us to know is, in what direction to go to reduce the losses, and approximately what the minimum possible loss is, so that we can approach it as closely as practicable and do not waste efforts in trying to realize something which is impossible.

The conditions of minimum loss for a given normal current are illustrated in the following simple case: Let ee , Fig. 1, be an electrode surrounded by a perfect heat insulator except at its ends, which are kept cool, say, with a water jacket. Let a rela-

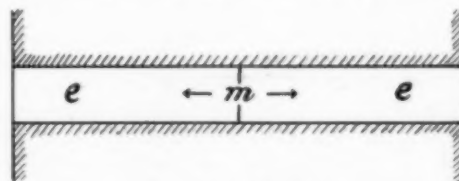


FIG. 1.—ELECTRODE.

tively large current be passed through it. This will heat it to a high temperature at the middle m . When the stable state is reached all the C^2R heat will flow out at the two ends, and none will flow across the middle section m .

If now this embedded electrode be imagined to be cut into two parts at m , and if these two parts are made the two end walls of a furnace with these conductors as its electrodes, as in Fig. 2, the temperature of the interior of the furnace being the same as that at m was in Fig. 1, it is evident that the heat flow will not be altered, while the same normal current flows, and that, therefore, there will be no loss of heat from the interior of the furnace through the electrodes.

That this is the condition of minimum electrode loss will be shown later.

The above laws will be further explained and illustrated in

the latter part of this article. The reason why they have apparently not been known before seems to be that the determination of the flow of heat in an electrode involves a problem in heat conduction which no one seems to have investigated, namely, the law according to which the conducted furnace heat and the C^2R heat generated in the electrode itself combine to flow out at the cold end. It is evidently incorrect to calculate each of these two flows of heat separately and add them to get the total, as was commonly done, because two quantities of heat flowing together in the same conductor change the temperature conditions under which each was calculated; and, as

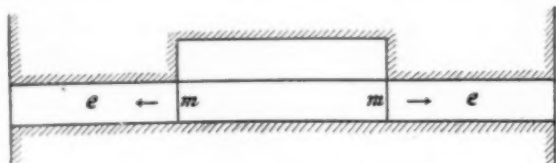


FIG. 2.—FURNACE WITH ELECTRODES.

was shown in Figs. 1 and 2, it is possible to make one of these act as a check valve, so to speak, to stop the other from flowing.

The fundamental law of the combined flows of these two dissimilar heats may be determined by the calculus, as follows:

Proof of the Fundamental Equation.

Let ab , Fig. 3, be a conductor of heat and electricity of uniform section, which is surrounded by a perfect insulator of electricity and heat except at its ends. Let the one end a be kept at a temperature T by some source outside of it, and the other end b kept at zero; hence heat will flow through it from a to b . In addition to this, let an electric current flow through it which sets free heat in its interior at a uniform rate in watts per inch. The problem then is: how much heat will flow out of the cold end after the stable state has been reached?

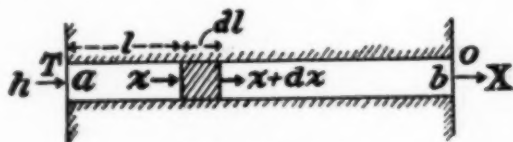


FIG. 3.—ELECTRODE.

Let:

X = total energy flow in watts passing out at the cold end.

x = total energy flow in watts passing through any section at a distance l from the hot end.

H = total heat flow in watts which would flow from the hot to the cold end when there is no electric current.

h = heat flow in watts which actually enters the hot end.

W = total heat flow in watts generated in the rod by the electric current; that is, the total C^2R heat.

w = this C^2R heat per inch of length = W/L .

T = temperature of hot end in centigrade degrees, when cold end is at zero, or the drop of temperature when it is not.

t = temperature at any given section at a distance l from the hot end when the cold end is at zero.

L = total length in inches.

l = any given distance from the hot end in inches.

S = cross-section in square inches.

k = mean heat conductivity in gram calories per second for 1 in. length and 1 sq. in. section for the given range of temperature.

r = mean electrical resistivity in ohms for 1 in. length and 1 in. section, for the given range of temperature.

C = the current in amperes.

R = the total resistance in ohms.

$j = 4.186$, namely the electrical equivalent of heat; that is: gram calories per second $\times j$ = watts.

Let dl be an infinitely short section at a distance l from the

hot end, t be the temperature at the hot side of this section, and let the heat which flows into this section from hot end be x . Then, as the heat flow follows some law, the heat which flows out of that section is $x + dx$. Hence, the heat which has been added is the difference, namely, dx . But this heat, which has been added by the electric current, is also equal to $w dl$. Hence

$$dx = w dl \quad (1)$$

but

$$x = -jkS \frac{dt}{dl} \quad (2)$$

in which dt/dl is the heat gradient, which is negative because it increases as t diminishes. Differentiating, this gives

$$dx = -jkS \frac{d^2t}{dl^2} dl,$$

which combined with (1) and reduced gives

$$\frac{d^2t}{dl^2} = -\frac{w}{jkS}$$

Integrating this once, gives

$$\frac{dt}{dl} = a - \frac{wl}{jkS} \quad (3)$$

and a second time,

$$t = b + al - \frac{wl^2}{2jkS} \quad (4)$$

Now, when $l=L$ then $t=0$, and when $l=0$ then $t=T$. Substituting these values in this equation gives the values of the constants a and b as follows:

$$b = T$$

$$a = \frac{wL}{2jkS} - \frac{T}{L}$$

Substituting this value of a in (3) gives the value of the differential coefficient dt/dl in finite quantities; and this substituted in (2) gives the general equation for the flow of energy at any point l inches from the hot end:

$$x = \frac{jkTS}{L} - \frac{wL}{2} + wl \quad (5)$$

It will be seen that the first term is the total conducted heat H in watts when there is no current, the second is one-half the total C^2R heat, that is $W/2$, while the third term is the C^2R heat generated in the hotter part l . Hence, the general equation for the heat flow through any given section is

$$x = H - \frac{W}{2} + wl \quad (6)$$

Or, in other words, this means that at any point l inches from the hot end the flow of energy is equal to the total heat which would be conducted by the whole rod from the hot to the cold end in watts, when there is no current, less one-half the total C^2R energy per second in the whole rod, plus the C^2R energy per second generated in the part l .

Now, when $l=L$, then $x=X$, because it is then equal to the total flow out of the cold end; hence, as $wL=W$,

$$X = H - \frac{W}{2} \quad (7)$$

which is the fundamental equation sought. The heat which would be conducted from the hot end is

$$H = jkT \frac{S}{L} \quad (8)$$

and half the C^2R loss is

$$\frac{W}{2} = \frac{C^2r}{2} \cdot \frac{L}{S} \quad (9)$$

Hence, this fundamental equation means that the total energy flowing out of the cold end is equal to the sum of the heat which would flow if there were no current, and half the C^2R heat.

This equation may also be deduced by ordinary algebraic methods. It has also been checked by slightly different methods by Dr. H. C. Richards and Dr. W. S. Franklin; it was also determined by a slightly different method, quite independently, though subsequently by Dr. E. F. Roeber.

Other Analytical Deductions.

If in (6) l is made equal to O , then $x = h$; that is, the heat which enters the hot end is

$$h = H - \frac{W}{2}$$

or, in other words, the furnace heat which enters is equal to the difference between these two heats. Hence, in order to make $h = 0$, that is, to have this rod conduct no heat from the source at the hot end,

$$H = \frac{W}{2} \quad (10)$$

or, in other words, the heat which would be conducted if there were no current must be made equal to half the C^R heat. This is accomplished by proportioning the cross-section and length so that this equality results, as will be shown later.

Returning to the heat flowing out of the cold end (7), it will be noticed that the product of these two terms is, from (8) and (9),

$$\frac{C^R j k T}{2}$$

which does not contain the variables S and L , and is, therefore, a constant for any given conditions of a problem. But if the product of two variables is a constant, their sum (7) is a minimum when they are equal, and this sum X is then equal to twice either one of them. Hence, for the minimum flow of heat out of the cold end, that is, for the minimum total loss of energy in an electrode of a furnace,

$$H = \frac{W}{2} \quad (11)$$

As was shown above in (10), this equality also exists when no heat enters the hot end of the rod; or in furnaces, when no furnace heat leaves through the electrode. The total loss is

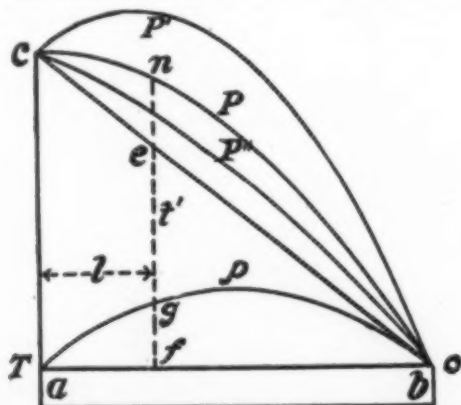


FIG. 4.—CURVES OF TEMPERATURE VARIATION IN ELECTRODE.

equal to their sum (7), but as they are now equal, this sum is equal to either $2H$ or to W . Or, put into words: The total loss is least when the heat which would be conducted if there were no current is equal to half the C^R heat; there is then no loss of heat from the furnace, and the loss through the cold end is equal to the C^R loss.

Returning now to the general equation (4) for the temperature t , substituting in it the values of a and b given just below it, and replacing wL by W gives

$$t = T - \frac{Tl}{L} + \frac{Wl}{2jkS} - \frac{wl^2}{2jkS} \quad (12)$$

which is the general equation of the temperature, and, therefore, gives the heat gradient along the rod. It will be seen to be parabolic.

Making w equal to zero in this equation, that is, when no electric current is flowing, the heat gradient is a straight line ceb , Fig. 4, in which ab is the conductor and a the hot end.

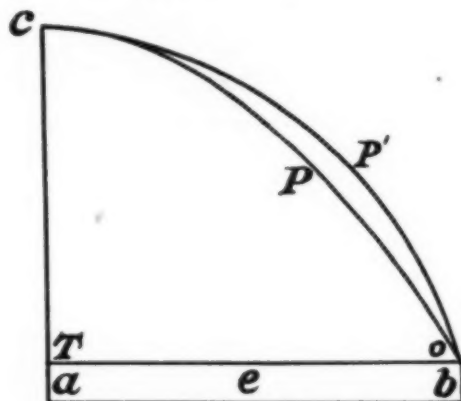
Making T equal to zero in (12) gives

$$t = \frac{Wl}{2jkS} - \frac{wl^2}{2jkS} = \frac{(W-wl)l}{2jkS} \quad (13)$$

which is the equation of the parabola p , Fig. 4; this, therefore, is the heat gradient for the case shown in Fig. 1 above in which a rod is heated by a current while imbedded in a heat insulator, and is cooled only at the two ends.

It was shown above that the total loss of heat from the cold end is least when the conduction heat is equal to half the C^R heat—that is, when the quantity (8) equals $W/2$. Making these two quantities equal, solving for T and substituting in (12), gives

$$t = \frac{WL}{2jkS} - \frac{wl^2}{2jkS} = \frac{w}{2jkS} (L^2 - l^2) \quad (14)$$



when stated in terms of the dimensions, physical properties, temperature and current, is:

$$X = 4.186 k T \frac{S}{L} + \frac{C^2 r}{2} \cdot \frac{L}{S} \quad (18)$$

For a given normal current at which the furnace is to be operated it will be noticed from this formula (18) that when, by proper proportioning, the heat conduction loss when no current is flowing (the first term) is made equal to half the $C^2 R$ loss (the second term) then the two terms are equal, and their sum is therefore equal to the total $C^2 R$ loss. This is the condition of minimum loss as was described above.

For a given length, the first term (heat conduction) increases as the section increases and in direct proportion; hence, in Fig. 6, this quantity is an increasing one represented by an inclined straight line oh . The second term, however (half of

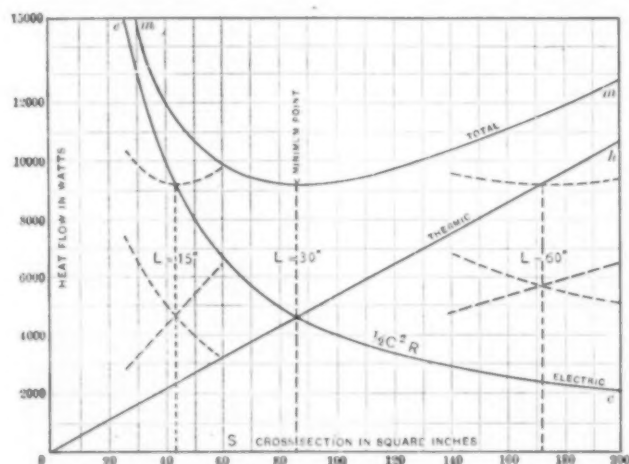


FIG. 6.—LOSS CURVES.

the electric loss), will decrease as the section increases, and in inverse proportion, hence this quantity is a decreasing one represented by the hyperbola ee .

The sum of two such quantities always has a minimum value, as is shown by the curve mm , which represents the sum of the two ordinates, and is therefore the curve of the values of X (in watts) in formula (18). It will be seen that this minimum point is reached when the two quantities are equal to each other—that is, at the point where the two lines intersect; it is, therefore, at this point that the conduction loss is equal to half of the $C^2 R$ loss, which is the condition stated above.

If the same sets of curves be drawn for several other lengths of electrodes, as shown in dotted lines in Fig. 6, it will be noticed that the total loss at the corresponding minimum point always has the same value, namely, the height of the upper curve measured at its minimum point. This means that the minimum loss is determined only by the material, the temperature and the current, and cannot be further diminished by changing the dimensions. It is, therefore, a fixed quantity, determined by the given conditions of material, temperature and current, and no possible change of dimensions can reduce it. To reach this minimum requires a certain proportion between the length and the cross-section, as will be discussed later, hence no further change of dimensions can possibly reduce it.

Let mX be this minimum total loss in watts. Making the two terms in formula (18) equal, solving for the ratio of S to L and substituting in (18) gives

$$mX = 2.894 C \sqrt{k r T} \quad (19)$$

from which the minimum loss in watts can readily be calculated for any given case. The constant 2.894 is a purely mathematical one and includes no physical properties.

It is of considerable interest to note that this formula shows that this loss is independent of the dimensions and is fixed by the current, temperature and material (k and r). It is also of

interest to note that it increases in direct proportion with the current and not with its square. It is independent of the amount of energy in the furnace, being a function merely of the current, which means that for a given input in kilowatts in the furnace the electrode loss becomes smaller if the current is decreased and the voltage increased. For a given normal current, material and temperature, the conditions are fixed, and the electrodes may be determined; the minimum loss then, of course, applies to this normal current and to none other, for if with the electrode thus determined the current falls below this normal, the loss will of course be less, but so will also be the energy in the furnace. What is said above, of course, applies only to the normal current specified for operating that furnace.

The formula also shows that the minimum electrode loss increases only as the square root of the temperature, and not as the temperature itself, as might at first be supposed. This means that the temperature may be increased considerably without increasing the loss greatly.

The same is true of the heat conductivity k and of the electrical resistivity r , either of which must be decreased considerably in order to better the loss appreciably. Hence, the choice of material is not as important a factor to reduce the loss as might at first be supposed, and such choice may, therefore, often be determined by other considerations, such, for instance, as size, convenience in handling, size of water jackets, terminals, etc., all of which will be shown to be far more favorable for graphite, for instance, than for carbon, although the minimum possible loss of energy seems to be slightly greater than for the latter. It will also be found that this minimum loss is in most cases quite small, much smaller perhaps than is generally supposed, hence a further reduction by reducing any of the determining factors in formula (19) should be carefully considered with respect to any possible attending disadvantages, chiefly as to size, as it may not be worth making. To reach this minimum loss with carbon, for instance, requires the electrodes to be far larger in section than for graphite (for a given length), and if not made of this much greater size the loss will not be the minimum, and hence may then exceed that of graphite. The differences between the minimum losses in these two materials (provided the best proportions can be realized in practice, which may not always be the case with carbon) does not seem to be great, yet the difference in the sizes is very great, as will be shown below.

Another feature should be considered. In high temperature furnaces carbon may graphitize partly, and if it was correctly proportioned at first, it will evidently not be so later on, hence the loss will then become greater again. Graphite is stable and does not change, hence, if correctly proportioned at the start, it remains so.

The resistivity r may be replaced by the reciprocal of the electrical conductivity K , and for comparing the qualities of materials as such the current and temperature may be made unity; the result will then represent the loss in watts per ampere for one degree of temperature, and will, therefore, be characteristic of the material itself. Making these substitutions gives

$$mX' = 2.894 \sqrt{\frac{k}{K}} \quad (20)$$

K is in reciprocal ohm (mho) cubic inch units. This shows the interesting fact that the minimum loss depends on the ratio of the two conductivities; both may be large or both small, and yet give the same result, as far as the loss is concerned. The smaller this ratio, the better the material, as far as the minimum loss is concerned. Moreover, the loss varies with the square root of this ratio, which must, therefore, be considerably diminished in order to reduce the loss materially.

In order to improve materials for electrodes when this minimum loss is the criterion, the electrical conductivity should be increased as much as possible and the heat conductivity

diminished as much as possible; but it is their ratio that is the deciding factor, hence the heat conductivity may even be increased and yet the ratio may be less, if the electrical conductivity has increased still more in proportion.

There is still another interesting feature about this minimum loss. The loss represented by formula (19) is also equal to Ce in which e is the drop of voltage in one electrode. Making this substitution gives

$$e = 2.894 \sqrt{\frac{r}{kT}} \quad (21)$$

which will be seen to be independent of the current, and which, therefore, means that for every material (k and r) there is a characteristic minimum drop of potential in the electrodes for one degree of difference of temperature, below which voltage it is not possible to go without again increasing the loss; and this is independent of the capacity, the dimensions, and even the amount of the normal current, the total drop being dependent only on the temperature. It might be termed the minimum electrode voltage of that material, as it is a characteristic property of it as an electrode material.

If by the term electrode efficiency is meant the voltage between the two inside or hot ends of the electrodes, divided by the voltage between the two outside ends, its highest possible value is determined by the total voltage of the furnace, the temperature and the material, and is independent of anything else. Hence, for any given electrode material and temperature drop, the furnace voltage necessary to give any desired electrode efficiency may readily be calculated.

This minimum electrode loss is not merely a theoretical ideal which it is impractical to reach, but it is an eminently practical result which could probably be readily reached in most furnaces, with graphite if not with carbon, if the data for its proper determination, namely, the two conductivities, exist. Attention should, however, be called to the flatness of this minimum curve *mm*, near its minimum point, which means that great accuracy in the proportioning is not necessary, as slight variations in the proportions in either direction will make only a small difference in the total loss. For instance, in the case shown in Fig. 6 a change of 10 to 20 per cent in the cross-section near the minimum point will increase the loss only about 1 to 3 per cent.

Proportions and Economy of the Electrodes.

Although the absolute dimensions of the electrodes are not fixed by the conditions for obtaining the minimum loss, yet the relation of the section to the length is. This is best shown analytically. If the two terms in formula (18) are made equal, which is the condition of minimum loss, the ratio of S to L is found to be a constant, determined by the material (k and r) the temperature and the current. That is, when

$$4.186 kT \frac{S}{L} = \frac{C^2 r}{2} \cdot \frac{L}{S}$$

then

$$\frac{S}{L} = 0.3456 C \sqrt{\frac{r}{kT}} \quad (22)$$

This means that to get the minimum loss under given conditions of material, current and temperature the cross-section must merely bear a certain relation to the length as given by this formula. The interesting conclusion from this is that any number of different electrodes will give the same result, as illustrated in Fig. 7, in which all have the same ratio of section to length, as required by formula (22). The cross-section in all these is 10 times the length in inch units. It thus leaves one a choice of either the length or the section, but not of both, and this choice does not concern the loss of power; it merely affects the economy of electrode material. Practical considerations usually determine the length, and it is, therefore, generally the cross-section which is to be determined from formula (22).

Notice should be taken of the fact that the numerical value of this ratio will be different for different units, as, for in-

stance, for inches and for centimeters; the actual sizes will, however, of course, be the same.

The rule concerning the economy of electrode material is, therefore, simply: *Make the electrodes as short as practical considerations will permit.* As the cross-section also diminishes with the length, the volume, or approximately the cost in dollars, diminishes as the square of the length. Hence the great importance of making the electrodes as short as possible when the economy of the electrode material is of importance; this choice of length will not affect the power loss and can, therefore, be decided on its own merits and without regard to the power efficiency.

For a given length the formula may be written in the form

$$S = 0.3456 CL \sqrt{\frac{r}{kT}} \quad (23)$$

which means that for a given length, temperature and material, the section increases in direct proportion with the current; hence the importance of producing the required heat in the furnace by as high a voltage as possible, so as to diminish the

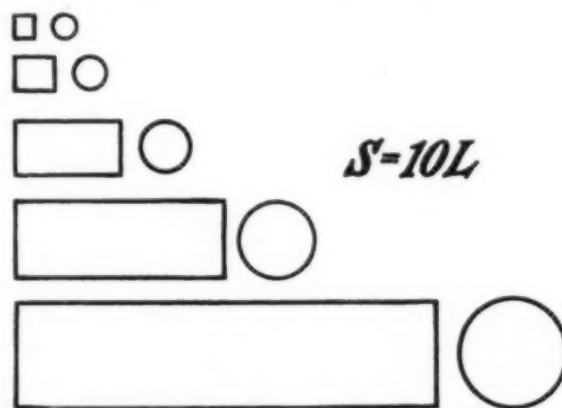


FIG. 7.—DIFFERENT ELECTRODES WITH THE SAME RATIO OF SECTION TO LENGTH.

normal current; this will not only make the electrodes smaller in the direct proportion as the current is diminished, but, as was shown above, it also diminishes the lowest possible loss of power in the electrodes, hence it is a double gain.

It will be noticed from (23) that the section diminishes as the square root of the temperature—that is, for higher temperatures it becomes smaller.

Letting the current density in amperes per square inch be represented by Cd , then formula (22) reduces to

$$Cd = \frac{2.894}{L} \sqrt{\frac{kT}{r}} \quad (24)$$

which shows that the proper current density to obtain the best possible proportions varies inversely with the length, and, therefore, with the section; hence it is quite incorrect to proportion electrodes on the basis of a fixed current density, as is often done. For any assumed length, the resulting current density can readily be calculated from this formula so as to compare it with the maximum which the material will stand; if water-cooled at the outer end, it will stand much more, hence water-cooling results in an economy of material.

Making C and T equal to unity in formula (22) gives:

$$\frac{S}{L} = 0.3456 \sqrt{\frac{r}{k}} \quad (25)$$

which shows that per ampere and for one degree temperature there is a definite best proportion of section to length for each material, which is a characteristic of that material and below which it is not possible to go in economizing the material without increasing the loss. Hence this figure affords a good means of comparison of different electrode materials when the economy of the material is the criterion. It shows that in this respect graphite is far superior to carbon, as electrodes of the former are very much smaller, as will be shown later.

Substituting in (25) the electrical conductivity K for the resistivity r , as was done in formula (20) for the convenience in making comparisons, this formula (25) reduces to

$$\frac{S}{L} = 0.3456 \sqrt{\frac{1}{Kk}} \quad (26)$$

This shows that as far as economy of material is concerned, that material is best in which the product of the two conductivities is greatest. Hence, to improve a material in this respect either or both should be increased. But the improvement in economy is only in proportion to the square root and hence is not as great in percentage as the improvement in either of the conductivities.

Comparing this formula (26) with the corresponding one (20) for the minimum loss, it will be noticed that the requirements for economy in material (26) and for economy of power (20) are different, and in some respects antagonistic, hence the choice of the material depends somewhat on the relative importance of these two economies. With graphite and carbon, for instance, according to the best though crude figures available for the two conductivities, the electrodes become much smaller for graphite, but the minimum loss is slightly less for carbon, provided both have their best proportions and, of course, the same length. Hence the question arises, is it worth while to use the far larger carbons than the much smaller graphites in order to diminish an already low power loss slightly? Numerical examples will be given below.

In this comparison of (20) and (26) it will be seen that both economies are improved by an increase of the electrical conductivity alone, hence this is always desirable. An increase in the heat conductivity alone improves the economy of material, but diminishes the economy of power; a decrease in the heat conductivity alone, improves the economy of power but increases their size. The final criterion depends on their quotient and product, as was described.

Rules for Designing Electrodes.

From the above, the rules for the guidance of the designer may be briefly summarized as follows:

The temperature and the kilowatts are always given in the problem. The two conductivities or resistivities of the proposed materials must, of course, be available. From the kilowatts, make the current as small and the voltage as high as practicable. From formula (22) calculate the proportion of the section to the length. The length is generally fixed by the width of furnace walls or other considerations; the only rule is to make it as short as practicable, remembering that the volume and therefore approximately the cost diminishes as the square of the length; this length then determines the section. The current density (24) is not a factor in calculating the proportions of electrodes except in so far that it should not exceed practical limits.

The electrode loss will then be the minimum possible and is determined from formula (19) in watts; this is for one electrode and must, therefore, be multiplied by 2 to get the total. The electrode efficiencies are then readily determined.

These calculations should be repeated for each of the different materials available and the various advantages and disadvantages due to their different sizes, losses, terminals, etc., should be carefully weighed.

Never compare two electrodes of the same size but of different materials having different conductivities; such a comparison is unjust to either one or the other or both, as also to the designer, because it gives him an unwarranted confidence. They can be properly compared only when both have their best proportions.

Numerical Examples.

To give numerical examples for illustrating these laws of electrode losses and their best proportioning requires that the two conductivities be known for those ranges of temperature. These constants, unfortunately, do not all exist in satisfactory

form, but now that the laws of the electrode losses have been definitely established, these constants will no doubt be forthcoming in the near future. For the present, therefore, we must content ourselves with the best data that are available, but it must not be forgotten that the comparisons based on them are no more reliable than the original data, and that the present results are, therefore, only approximate. The numerical examples are given here chiefly as illustrations and rough approximations, and not as accurate and reliable figures. But they are, of course, far better than those determined by the former methods based on current densities, the addition of the two losses, and on a comparison of electrodes of the same size but of different materials.

The electrical resistivity of graphite is probably quite close to 0.000333 ohm for 1-in. cube, taken lengthwise. But this is at normal temperatures; it falls quite appreciably at higher temperatures reaching as low as about 64 per cent. A fair average for a range of temperature from 100° C. (water jacket) to 1700° C. (approximately that of iron furnaces) is therefore about 0.000266.

The absolute heat conductivity of graphite has apparently not been determined, notably not at the higher temperatures. According to FitzGerald it is 18 times that of carbon, while according to Hansen it is about 8 times carbon. Both are only relative and not in absolute units. The former figure seems to bring it up higher even than many metals and is, therefore, probably much too high; the second was determined under furnace conditions and is, therefore, probable more nearly correct. It will be so assumed here.

The heat conductivity of carbon is also not known. The only figure obtainable is 0.0103 in absolute units for retort carbon (about 0.026 in cubic inch units), which seems rather low for electrode carbons, which are certainly more like the metals than the vitreous retort carbons are. According to Hansen, it decreases at higher temperatures. It is, therefore, probably not far wrong to assume it to be 0.03 in cubic inch units. Graphite on the basis of 1 to 8 would therefore be 0.24.

The electrical resistivity of carbon seems to average about 0.00150 in ohm cubic inch units for the smaller sizes, but according to Hansen, it increases to 0.00337 for 6 in. \times 6 in. and to 0.0055 and even 0.0100 for 18 in. \times 18 in. As carbon electrodes must be very much larger than graphite, a comparison between the two becomes fairer if some account is taken of this higher resistance for the larger sizes; it may therefore be assumed to be 0.0025, and, as with graphite, that it diminishes with the temperature, making the average between 100° and 1700° C. about 80 per cent of this, which is 0.002.

Hence, the constants to be used here are, in cubic inch units, for a range of 100° to 1700° C.; graphite, $r = 0.000266$, $k = 0.24$; carbon $r = 0.002$; $k = 0.03$.

From formula (19) it will be seen that the minimum loss, as far as the material is concerned, is proportional to the square root of $k \times r$, which for graphite is 0.0080 and for carbon 0.0078; hence the difference in the losses will be only about 3 per cent in favor of the carbon.

Similarly from formula (22) the cross-section for any given length, as far as the material is concerned, is proportional to the square root of r/k , which for graphite is 0.0333 and for carbon 0.258; hence, for any specified furnace, carbon electrodes would have to have a cross-section $0.258/0.0333 = 7.75$, or nearly 8 times that of the graphite for the same furnace. The question, therefore, arises, is this very small gain in power worth the disadvantages of the enormously larger electrodes with their larger terminals, water jackets, etc.?

Let the capacity of a furnace be 500 kw and let it be decided to run it at 50 volts and 10,000 amp; the temperature to be 1700° C. inside and 100° C. at the outside ends of the electrodes. From formula (19) the minimum loss in each electrode will, therefore, be 9.15 kw for graphite; hence the loss in the two

¹According to figures obtained by the writer through the kindness of Mr. C. A. Hansen.

electrodes together, due to conduction and resistance, is only 3.66 per cent. For carbon it will be 8.96 kw or 3.58 per cent. It is to be noted how relatively small these actual losses are and what a small difference there is between graphite and carbon when they are properly proportioned. This difference is about 3 per cent of 3.55 per cent, or about 1/10 of 1 per cent of the total power. The curves of Fig. 5 are for the graphites for this furnace.

From formula (23) the cross-section for graphite in square inches will be 2.87 times the length in inches, and for carbon 22.3 times. Let it be determined from practical considerations that the length should be 30 in. and let the electrodes be round in section, then the diameter of the graphite will be 10.5 in., and that of the carbon 29.2 in. As stated above, the carbons will have nearly 8 times the cross-section of the graphites for the same length.

It will be seen that the carbon electrode will be about as large in diameter as it is long and is, therefore, entirely impracticable. For a length of 40 in. the diameters are 12.1 in. and 33.7 in. respectively; for 50 in., 13.5 in. and 37.7 in.; for 60 in., 14.8 in. and 41.3 in. and for 70 in., 16 in. and 44.6 in. In order to give a better idea of these proportions, they have

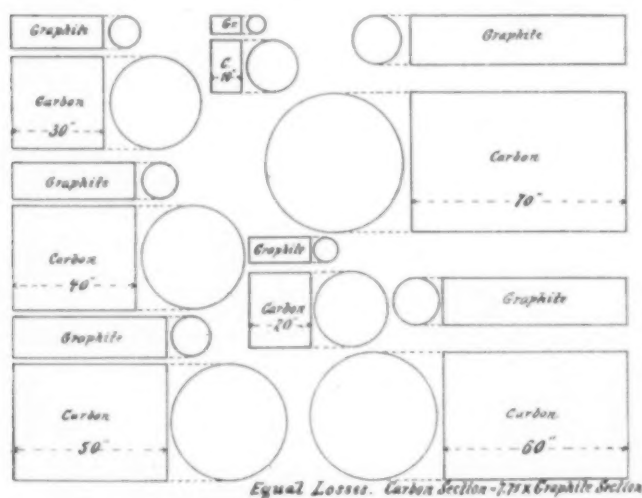


FIG. 8.—COMPARISON OF CARBON AND GRAPHITE.

been drawn to scale in Fig. 8 in pairs of the same length. For all these electrodes of the same material the loss is the same, that for the carbons being about 3 per cent lower than that for the graphites.

It will be seen what an awkward and entirely impracticable proportion the carbons have for such a furnace. To lengthen any of them appreciably for the same section, would increase the loss, and as the difference in loss is only 3 per cent, it would soon become greater than for graphite.

Hence the prevalent idea that the loss with graphite electrodes is always too great owing to their heat conductivity is a fallacy and is based on an improper comparison. As a matter of fact, it is their good heat and electrical conductivities that enable them to be made small and of such proportions that it becomes possible to obtain the minimum loss for such a large current furnace, which it is evidently impossible or at least impracticable to obtain with carbons, at least for this furnace, provided the assumed values of the conductivities are correct.

This illustration also shows quite strikingly the error committed when two electrodes of the same size but of different materials, are compared with each other. Either one or the other, and probably both, must have been badly proportioned; it was no doubt generally the graphite, which was much too large, and, therefore, naturally, chilled the furnace. One can readily convince himself that these are the best proportions by changing either the length or the section, when it will be found

by calculation that in every case the total loss will be increased. Formula (18) shows how this total loss may be calculated.

In comparing the quantities of electrode material (that is, the cost), one should, of course, compare the short graphite one with the much longer carbons, because the latter cannot be handled unless made sufficiently long. If, for instance, the shortest practicable carbon is 40 in. long, and graphite 20 in., the quantity of material in the former will be nearly 32 times as great. The drop of voltage in these electrodes, which is the same in all those of the same material, is determined from formula (21) or more directly from the above minimum loss, which was found to be 3.66 per cent for the graphite, hence $0.0366 \times 50 = 1.83$ volts, or 0.92 per electrode; and for the carbon 3.58 per cent or 0.90 volt per electrode.

Formula (21), of course, gives the same results, but to illustrate its application as giving the characteristic voltage drop of the material, substitute the constants for graphite and carbon, and make the temperature unity. This gives for graphite $e = 0.0231$, and for carbon $e = 0.0224$ as the characteristic minimum voltage drop for one degree for these materials. These are independent of the normal current for which the electrodes are designed—that is, they are the least voltage drop for any normal current, and are for one degree difference of temperature. Hence, the minimum voltage drop can be determined for these materials at once by simply multiplying these figures by the square root of the temperature. In the present case the temperature drop is 1600; hence, multiply by 40, which gives 0.92 and 0.90 as the two drops in voltages per electrode, regardless of which of the sizes of electrodes are chosen.

In conclusion, the writer desires to repeat that there are, of course, many other considerations besides the mere power loss and economy of electrode material which should be taken into consideration in the design of electrodes, some of which may at times outweigh the latter in importance; this depends on the particular conditions of the case. It is the duty of the designer to properly weigh all the various factors; he can, however, do this intelligently only when he knows what the ideal results are; the intention of the present investigation was, therefore, to assist the designer by showing what the best results are as far as it concerns only two of the many factors, the size of the electrodes and the power loss in them; the intention was not to attach undue importance to these two factors over the others. If, for instance, the consumption of an electrode in an arc furnace is in proportion to the quantity of electricity, it may perhaps be a distinct advantage to make them large so as to reduce the speed of feeding. If so, the above analysis will show that in such a case the length of the embedded electrode should be proportionally increased or else the power loss will become greater; it also enables one to determine what this increased power loss would be, and, therefore, whether it is worth saving.

PHILADELPHIA, PA.

Notes of Electrochemistry and Metallurgy in Great Britain.

(From Our Special Correspondent.)

Autumn Inertness.

The scientific institutions have, as is usual at this period of the year, suspended their meetings; and the official reports of the proceedings of the British association at Winnipeg have not yet come to hand. The exhibits at the Imperial International Exhibition do not present much that is new, and, generally, lack the interesting features of last year's. The Cowper-Coles Engineering Company is showing some noteworthy specimens, and demonstrates the processes employed in the welding of aluminium, a regenerative method of electrodeposition, and a process of "vapor-galvanizing."

A New Method of Galvanizing Iron and Steel Tubes.

A well-known firm, makers of wrought-iron and steel tubes, holds the patent rights in Great Britain for tubes of a new cold process of electrodeposition for which many advantages are claimed. The pure zinc is deposited in a very minutely divided condition on the suitably prepared surface in a manner which appears to result in amalgamation. The evenness of the coating is maintained over the whole of the interior and exterior surfaces, including threads, and any variation of density is said to be impossible. The deposited zinc is so firmly united with the iron that tubes may be bent after galvanizing without any scaling or flaws occurring, which could not be done with tubes coated by the hot process.

Greater durability is said to result from the evenness of the coating, together with maintenance of the full capacity of the bore, and greater protective efficiency is ensured by the rise of zinc having a high degree of purity. Defects are not concealed by this process, as is so frequently the case with the old method, and pitting, flaws, and other faults show up as plainly after coating as before.

It is further claimed that the new method tends to enhance the malleability of the metal, while the hot process causes brittleness. Finally, all the advantages mentioned are secured without any increased cost.

New Regulation for Tinning Works.

In February and March of this year a public inquiry was held, and the report of the commissioner, Mr. E. T. Lawes, has resulted in the issue by the Factory Department of the Home Office of regulations relating to the tinning of metal goods, such as iron drums, hollow-ware and harness furniture. The coating of metal articles with tin or with a mixture of tin and lead has been classed as a dangerous occupation, and the regulations—which, with one exception, come into operation on Oct. 1, 1909—are issued under the Factory and Workshop Act, 1901. The exception is the regulation providing that tinning shall be effected under adequate ventilation for the removal of fumes or dust, and this will take effect on April 1, 1910. Employers are required to provide lavatories with requisites for the same; and also, if the works be not closed during meal hours, a separate room for taking food. The employment of persons under 16 years of age is prohibited. Dipping-bath skimmings, floor refuse, and dust must be removed from every workroom, while the employees are to wash their hands before eating food or quitting the works, and are forbidden to prepare or consume food or drink in any room used for the process of tinning. Periodical medical inspection of the employees is provided for and the chief inspector of factories has discretionary powers as to exemptions.

A Regulator for Alternators.

A device resembling the compound or series winding in direct-current dynamos, in order to secure constant voltage under varying load, has been introduced in Messrs. Parsons' patent compound-wound alternator. This improvement is consequential on the application of the well-known fact that although an alternating current does not produce a uni-directional field it may exert considerable influence in concentrating the same. If, then, a "keeper" be applied to the magnet poles while a strong current flows through the windings, it follows that when the sectional area of the "keeper" is less than that of the limbs, the iron "keeper" will be more saturated than they. If the current be alternating, such saturation will prevent any great increase of leakage flux in one direction, but will at the same time lessen it very greatly in the reverse direction, thus reducing the leakage flux to a very great extent. In Messrs. Parsons' machines the leakage-path windings are disposed between the alternator windings and the neutral point, and their insulation is calculated for the full pressure in the main windings. The additions are strictly electromagnetic, without movable parts, varying contacts, solenoids or other such contrivances. No commutator is required to convert the

bi-direction current into the direct current. The machine can be utilized in the ordinary way in event of mishap in the new apparatus by removing it—which can be effected in a few minutes.

Marble Panels and Dampness.

The effect of dampness on marble panels is stated, in a recent issue of *La Nature*, to have serious consequences. On several distribution boards at 110 volts leakage to earth was directly due to the marble being in contact with damp walls. In one installation with a normal insulation resistance of 300,000 ohms the actual resistance never exceeded 25,000 ohms in consequence of a lightning arrester being fixed to a damp wall, while the marble had absorbed such a large quantity of moisture that the less to earth was easily shown by a galvanometer. In another case electrolytic action, caused by the moisture and the conductance of the damp marble, totally destroyed the copper plate of a lightning arrester connected to the positive pole of the line. Sulphate and carbonate of copper were formed and penetrated deeply into the marble panels, while the fixing screws were destroyed. It is clear that marble is not an efficient insulator unless protected from dampness. Direct contact with walls should not be permitted, and the deleterious effects of moisture can be averted by the use of packing pieces of paraffined wood coated with shellac with porcelain insulators interposed between the marble and the wood to secure circulation of air.

British Exports.

The values of the exports from Great Britain during the six months ended June 30 were: Iron and steel and manufactures thereof, 18,333,333; other metals, 4,000,000; machinery about 14,000,000. During June exports of iron and steel and manufactures thereof amounted to £3,073,091; other metals, £632,876; machinery, £2,304,092. Total British exports for June are valued at £29,717,975, and for the six months at £176,934,350.

The Iron and Steel Institute.

The program for the autumn London meeting has been issued. It includes arrangements for visits to the Royal Arsenal, the National Physical Laboratory, Portsmouth Dockyard, and the works of several prominent firms. The Institute is to be congratulated on devoting three days to the reading and discussion of papers, instead of—to use the British parliamentary expression—slaughtering the innocents on the second day. The actual business of the meeting will extend from Tuesday, Sept. 28, to Friday, Oct. 1, inclusive.

Electrolysis and Electric Traction.

The Board of Trade regulations have made it necessary that engineers should give careful attention to the bonding of rails on our electric traction systems, and the stringency of these regulations has resulted in electrolytic disturbances having been brought within very moderate bounds. If the resistance of the return is great, the current will find other paths than the rails, such as gas and water mains and lead-sheathed cables—for this is what really occurs when a current is said to return through earth—and will set up corrosion of the surfaces of such metallic conductors. The rate of corrosion depends on the quantity of stray current; but that serious mischief has been caused in this way is unfortunately only too well known. If the difference of potential between the extreme of the uninsulated return and the point nearest to the power station should exceed 7 volts immediate attention to its reduction is requisite. In a recent issue the *Engineer* calls attention to the troubles which have arisen at Winnipeg in consequence of no such salutary rules as those enforced by our Board of Trade having been observed, and deals with the report of Prof. L. A. Herdt upon the electrical conditions existing in the city, particularly in connection with the return current of the Winnipeg Electric Railway Company's system and its connection with the Government telephone cable system. This recently issued report shows how much serious damage can be done to water and gas mains in conse-

quence of leakage from badly bonded rails and high-resistance return circuit. The report of the city electrician shows that in six districts there can be no doubt as to holes and breaks in water pipes and lead-sheathed cables having been caused by electrolysis; and that in four districts this is due to the bad condition of the bonding. Professor Herdt recommends that the practice of bonding the tracks to water and gas mains should be abandoned, because, whilst affording local protection, it has undoubtedly encouraged leakage currents and intensified electrolysis troubles. The article concludes by approving Professor Herdt's recommendation of the erection of a sub-station with the view of reducing the return current through the rails in the center of the city and his insistence on good rail-bonding.

Market Report for August, 1909.

Scotch pig rose slightly to steady at 56/s. since moving more sharply to meet present revival, to 58/3, present 57/3.

Hematite jerked on the 4th sixpence, afterwards rose from 56/4 to 57/4 on the 17th, afterwards unsteady to firmer at 58/.
 Antimony, black sulphide powder, per ton.....£22. 0. 0
 Sulph. of ammonia, f.o.b. Liverpool, per ton..... 11.10. 0
 Copper sulphate, per ton..... 18.15. 0
 Caustic soda, white, 77 per cent..... 11. 2. 6
 Bleaching powder, 35 per cent..... 4. 5. 0
 Shellac, standard T. N. orange spots, per cwt..... 3.16. 0
 Carbolic acid liquid, 97 to 99 per cent., per gal..... 11
 Creosote, ord. good liquid, per gal..... 2½
 Naptha solvent, 90 per cent., 160° C., per gal..... 10
 Rubber, Para fine, per lb..... 8s. 3d.

Tin is decidedly stronger than at the beginning of the month. Commencing (on the 3d) at £133.3.4, it fell on the 6th to £132.3.4, then rose to £136 on the 16th, closing at £135 to £137 (28th).

Copper rose slightly to the 10th, being low at £57.15.0; continued to rise to £60.5.0, and has since fluctuated between £58 and £60, present price £59.7.6.

Eng. Lead steady, about £12.15.0.

Iron, Cleveland warrants inclined to rise since the 5th from 49/10 to 50/4 on the 17th; present price 50/11 (27th) brisk.

LONDON, August, 1909.

RECENT METALLURGICAL AND ELECTRO-CHEMICAL PATENTS

Iron and Steel.

Electric Steel Refining.—The U. S. Steel Corporation, by adopting last year the Héroult furnace for their South Chicago and Worcester plans, has become the pioneer of the large electric steel furnace in this country. Evidence of the quiet way in which the Steel Corporation has been interested for a longer period in electric steel refining, is found in a recent patent of William R. Walker (application filed April 20, 1906). It relates to a combination of converter and electric furnace. He treats molten pig iron in an acid-lined Bessemer converter in the ordinary way until it has been substantially desiliconized and until the carbon has been removed or to somewhat above the limits ordinarily obtained in the use of the Bessemer converter, enough carbon being left remaining (preferably from 0.04 per cent to 0.3 per cent or thereabout) to prevent an oxidized condition of the metal and to enable the metal to remain sufficiently fluid to permit its ready transfer from the converter. He then takes this desiliconized and nearly decarbonized metal and—either directly or through an intermediate mixer—introduces it into an electrical furnace, with a basic lining, adding iron oxide together with burnt lime. The reaction caused by the basic additions, together with the continued heating is to dephosphorize and desulphurize the metal, the phosphorus passing into and becoming combined with the resulting slag. Mr. Walker says: "This process enables me to improve the product of the Bessemer converter in such manner as to obtain steel of the quality produced from the open-hearth furnace or by the crucible

process, and enables me to employ for the Bessemer converter iron containing more phosphorus than is permissible in so-called Bessemer iron, for the acid Bessemer process does not remove phosphorus, and any phosphorus contained in the pig iron charged into the converter will appear in the resulting steel." In his combination process Mr. Walker thus aims at the same ends as the Héroult process, but the combination is somewhat different, since in the original Héroult process the treatment is carried further than is proposed by Walker. Héroult removed the phosphorus in the converter, but thereby overoxidized his metal, so that his electric furnace treatment involved deoxidation, desulphurization, and recarburization. However, there have recently been some very interesting developments in the removal of phosphorus in the electric furnace, though it is still too early to report them. (934,247, Sept. 14, 1909.)

Induction Furnace.—In the electric induction furnace the magnetic leakage fluxes around the primary coil and around the secondary melting channel exert a considerable influence on the working conditions (power factor, efficiency) of the furnace. The object of a patent of Otto Frick is to suppress, to a considerable extent, this leakage flux, especially around the primary coil. For this purpose he places "around the field core a short-circuited conductor having two coils placed at a dis-

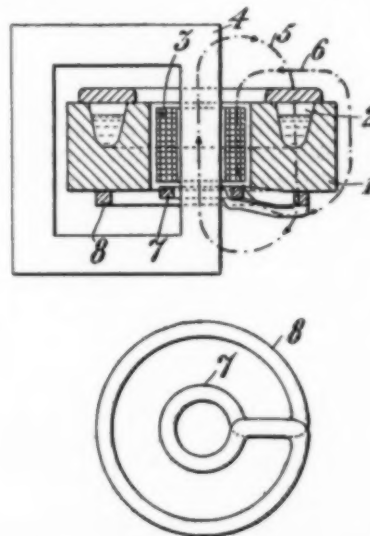


FIG. 1.—FRICK INDUCTION FURNACE.

tance from each other and wound in opposite directions, each coil consisting generally of only one winding, and connected in such a manner as not to be effectively induced by the main field, whereas the lines of force of the leakage field or fields pass through the closed circuit of the conductor, and excite therein a current counteracting the said field." Such short-circuited conductors are termed leakage-field coils. Fig. 1 shows one form of the arrangement, the lower diagram being a plan view of the short-circuited conductor; 2 is the usual annular melting channel, 3 the primary coil surrounding the transformer core 4, while 5 and 6 represent the limits of the primary and secondary leakage fields, respectively. To neutralize the leakage field from the primary coil, a short-circuited conductor or loop is provided, consisting of a central part 7, right below the primary coil, and an outer part 8, whose diameter is so large that it substantially incloses the leakage field of the primary coil and which is so arranged that the current in the same will run in opposite direction to that in the part 7. The main field in the closed iron core exerts the same inducing action in the parts 7 and 8 of the short-circuit loop or conductor 7, 8, and inasmuch as these parts are connected in series so that the induced currents will flow in opposite directions, the result of this induction will be zero. The leakage field of the primary coil flowing between the parts 7 and 8 excites in the

short-circuit conductor a current counteracting the leakage field. As indicated in the drawing, also a part of the leakage field of the secondary conductor passes through the space between the loops 7 and 8 formed by the short-circuit conductor, and inasmuch as this field has the same direction as the primary one, also this leakage field is partly counteracted by the current produced in the short-circuit conductor. Various modifications of the arrangement are shown. (933,169, Sept. 7, 1909.)

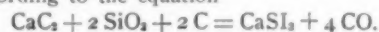
Refining Steel or Other Metals.—To produce special steels, etc., L. Hippolyte Baraduc-Muller places bricks or blocks containing the elements to be embodied on the molten steel or metal bath. The bricks are formed of oxides of nickel, chromium, manganese (or whatever metal is desired to be added) and siloxicon or silicon carbide (carborundum) or carbo-silicon Si_4C ; the following are three examples of composition of these bricks:

1. Oxycarbide of silicon (siloxicon).....	0.270
Oxide of nickel	1.225
Lime	0.056
Magnesia	0.040
Sodium carbonate	0.106
	1.697
2. Carborundum amorphous or crystalline....	0.400
Green oxide of chromium	0.760
Lime	0.056
Magnesia	0.040
Sodium carbonate	0.106
	1.362
3. Carborundum amorphous or crystalline....	0.400
Manganese dioxide	1.740
Lime	0.056
Magnesia	0.040
Sodium carbonate	0.106
	2.342

These bricks have a density from 2.05 to 2.65, while that of the metallic bath is from 7.1 to 8.9, so that the bricks float on the bath and soon assume a high temperature, causing the siloxicon or carborundum or carbo-silicon to react on the metallic oxides and produce the desired metal, alloy or silicide. The latter, having a higher density than the brick, sinks down into the bath, which is being stirred to facilitate dissemination. The bricks are consumed gradually in a relatively short time.

The bricks are made as follows: The ingredients are ground to a fine powder, and when a peroxide of a metal is involved a proportional quantity of powdered coal is added, then 10 per cent to 25 per cent of clay or clay-marl melting at about 1220°C . is added. When the mixture is homogeneous 5 per cent to 10 per cent of water is added, containing one-quarter to one-half of its weight, according to the case, of neutral silicate of soda at 42°Baume . The mixture being moistened in a homogeneous manner, is granulated while fresh through a sieve having large meshes and formed in molds into bricks under a pressure of about 350 kg per square centimeter. When the bricks are taken out of the mold, they are dried in the open air or by artificial heat. The bricks when dried are sufficiently resisting and hard to be handled and transported without breaking. To make them extremely hard they may be baked like building bricks to a temperature of 1000°C . at the most. The bricks may be agglomerated with magnesia and magnesium chloride in solution, or with a small quantity of cement or like material. The bricks thus worked bear very well all variations of sudden changes in temperature. It is claimed that the reactions between the metallic oxides and the siloxicon or carborundum, etc., yield nearly theoretical results, so that alloys or steels of definite composition are produced in one operation, without a separate production of the metal, alloy or silicide in a special smelting operation. (933,357, Sept. 7, 1909.)

Calcium Silicide.—Calcium silicide has been found to be an excellent refining agent for metals (especially steel) on account of its desulphurizing, dephosphorizing and deoxidizing properties. A new and very simple process of manufacturing it is patented by T. L. Willson and M. M. Haff. A metallic carbide of an alkaline earth, such as calcium carbide, is mixed with silica and enough free carbon added to satisfy the oxygen of the silica. Satisfactory proportions for the mixture are as follows: calcium carbide 64 parts, silica 120 parts, carbon 24 parts. In subjecting this mixture to the heat of an electric furnace, calcium silicide, probably of the formula CaSi_2 , is formed, according to the equation



Instead of calcium silicide another carbide like barium carbide may be used. (934,379, Sept. 14, 1909.)

Graphite Rock as Reducing Agent.—For the reduction of iron ore in the electric furnace, K. A. F. Hiorth proposes to use natural graphite rock as reducing agent. Natural graphite rock (not pure graphite) contains, in addition to silica, minerals of a basic nature which act as a flux. Graphite rock containing silica is found in large quantities, but is valueless for lead-pencil or crucible material and, therefore, forms at present no valuable raw material, the refining of which would be remunerative. Another advantage is that this graphite rock can be had substantially free from sulphur and phosphorus. In this way it is possible to produce a very pure iron directly from the ore in the electric furnace. (934,170, Sept. 14, 1909.)

Galvanizing.—A new electrolyte for producing hard and smooth deposits of zinc on iron and steel, is patented by Mr. Abraham Van Winkle (Hanson & Van Winkle Company, of Newark). The electrolyte is a solution containing fluosilicate of zinc, in combination with salts of aluminium or other salts of zinc, with an addition of a small quantity of gelatin previously dissolved, or other organic substance, that tends to improve the character of the deposit. This electrolyte remains clear in operation, acts freely on the anode, and permits the use of a solution as strong as 30 per cent Baume. (930,815, Aug. 10, 1909.)

Zinc.

Electric Smelting of Zinc-Lead Ores.—The difficulties of the metallurgy of complex zinc-lead ores forming slag are well known. If treated like pure zinc ores in retorts, the slag formed will soon destroy the retorts. If an attempt is made to smelt such ores in a blast furnace the lead is recovered, but the zinc is not recovered but is burnt to zinc oxide, which tends to clog up the furnace. When ores contain relatively small quantities of zinc, with lead and silver, the usual practice is to smelt them in a blast furnace for the lead and silver without recovering the zinc, which to a limited extent can be dissolved in the slag in the form of zinc oxide and can thus be eliminated. Such a treatment is possible with ores containing no more than 10 or 15 per cent zinc. There are, however, large deposits of lead-zinc sulphide ores, containing, for instance, 30 per cent zinc and 10 per cent lead, which have heretofore been commercially neglected. For the treatment of such ores an electric process of Mr. Fred. T. Snyder is specially intended. Mr. Snyder is well known to our readers as one of the pioneers of electric zinc smelting.

The ore having first been roasted to convert the sulphides into oxides, is mixed with fluxes such as lime and iron (unless already present) in such proportions as when smelted to produce a slag which will form at a temperature between the volatilization temperatures of zinc and lead (approximately between 1000° and 1100°C .; for instance, a slag containing 30 per cent lime, 30 per cent iron oxide and 40 per cent silica. This charge is first preheated in the presence of the carbon to be used in smelting, so as to start the process of reduction as far as possible and drive off the non-metallic gases while keeping the free surface of the charge sufficiently cool to prevent vaporization and loss of zinc at this stage. Finally, after such pre-

heating, the ore is smelted upon a slag bath, floated upon a molten lead electrode in a closed electric furnace from which air or other extraneous gas is excluded, the heat being produced by electric current passed through the slag between the molten lead electrode and another electrode (which may be of the same kind) in contact with the slag, the residues being completely fused. The metals are thus reduced, the molten lead sinking to the bottom of the furnace while the zinc is volatilized and escapes from the body of the charge as a gas, which is later condensed. An important consideration is the composition of the charge so that when smelted the slag will form at a temperature between the volatilization temperatures of zinc and of lead, and will possess the characteristics of low specific gravity and high electrical resistance, and will have practically no tendency to dissolve and retain zinc oxide. A slag which is high in lime or other ingredients which has a chemical tendency to displace zinc oxide in the combination will answer these requirements.

The Snyder furnace is shown in Fig. 2. The lower portion of the main chamber *a* of the furnace is divided by a bridge *b*, forming two wells *a'* and *a''*, which communicate by U-shaped passages with the exterior of the furnace, as shown in the right-hand diagram. Electric conductors *c* are dipped into the molten metal in the outer arms of these U-shaped passages, the molten metal in said wells *a'* *a''* serving as electrodes connecting with the slag bath of the furnace. There is sufficient material in the furnace so that the slag will rise to a level somewhat higher than the top of the bridge *b*. The two molten electrodes in the wells *a'* *a''* will be electrically united by the body of the slag which lies upon the bridge and floats upon said molten electrodes at either side of said bridge. The maximum heating effect of the current will be developed in the slag at the top, where it is most desired. A layer of carbon is maintained floating on the surface of the slag bath, and is heated thereby to in-

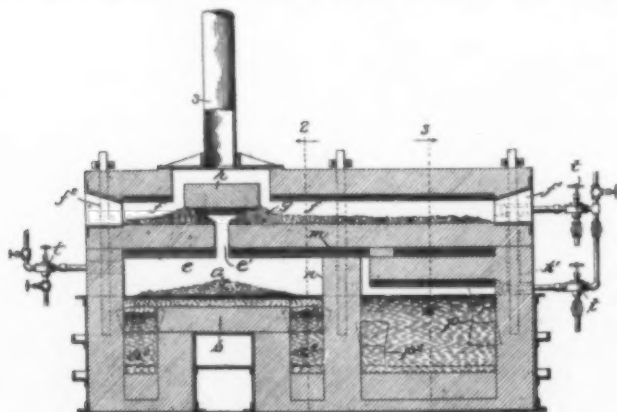


FIG. 2.—ELECTRIC ZINC FURNACE.

candescence. As the ore in the furnace is reduced, the elements of the charge go to renew and maintain the electric current; that is to say, the lead as it is reduced adds to the molten electrodes, while the other elements of the charge go to maintain the slag bath and the bed of incandescent carbon floating on its surface.

The furnace shown is constructed with the preliminary heating or roasting chamber *f* located above the main smelting chamber *a*. An opening *e'* is provided in the reverberatory roof

of the smelting chamber through which the roasted ore may be fed into said smelting chamber. Flues *k' k'* lead up through the wall of the furnace and open into the upper roasting chamber *f*, so that the uncondensed gases escaping through said flues may be burned in said last mentioned chamber to assist in the roasting process. A very considerable amount of energy is thus obtained from the carbon monoxide being burned to dioxide. From the roasting chamber the products of combustion finally escape through a stack.

The condensing chamber *k* is shown to communicate with

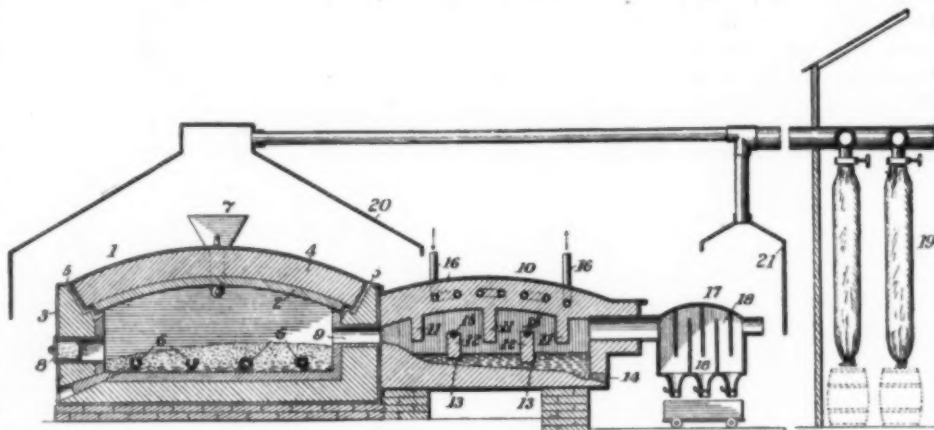


FIG. 3.—ELECTRIC ZINC FURNACE AND CONDENSER.

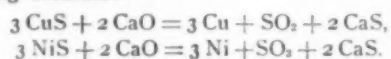
the chamber *a* by the passage *m*. (933,133, Sept. 7, 1909.)

Condensation of Zinc.—Fig. 3 shows an electric furnace 1 and a condenser 10 for zinc, designed by W. McA. Johnson, who is also a well-known, active pioneer of electric zinc smelting. The charge is introduced through 7 into the electric furnace and the heat is produced by means of the electrodes 6. The reduced zinc vapor escapes through 9 into the condenser 10, where it has to pass along a tortuous path on account of the partitions 11 and 12. In order to recover the zinc vapor in the form of spelter, the temperature of the condensing chamber must be maintained between definite limits, say between 415° and 550° C. For this reason, it may be necessary to heat the condenser during the early stages of operation, while during the later stages it may be necessary to cool it. Mr. Johnson therefore provides both heating and cooling means. The heating means consist of resistance conductors 15. The cooling means are the air conduits 16. Any zinc fumes which may escape from the condenser 10 are recovered in the collector 17. The collecting hood 20 above the furnace and the cooling hood 21 above the collector 17 are connected by a conduit with the usual fan and bags, and used for transporting to the bag house any zinc oxide which may escape. It seems that effective condensation is the main problem of electric zinc smelting. (933,843, Sept. 14, 1909.)

Nickel.

Nickel-Copper Alloys Direct from Matte.—In the manufacture of nickel or nickel-copper alloys the usual bessemerizing process of copper metallurgy cannot be applied, because the oxides and sulphides of nickel do not interact as in the case of oxides and sulphides of copper, so that in the case of nickel it has been the practice to produce matte in the form of sulphides, then to roast the sulphides to bring them to the

state of oxides, then to reduce the oxides with carbon to the conditions of spongy metal and to melt such sponge into the form of ingots. Mr. David H. Browne, of the Canadian Copper Company, has invented a method of producing nickel and copper-nickel alloys directly from the sulphide matte by introducing the molten matte into an electric arc furnace and subjecting it to the action of lime. At the high temperature in the furnace a reaction occurs between the lime and the sulphur contained in the matte so that the lime combines with the sulphur, producing sulphide of calcium and leaving the metal free from sulphur. The reaction which takes place is illustrated by the following formula:



The lime sulphide is lighter than the metal and will float on the surface as a slag. The slag may be thinned by the introduction of common salt, fluorspar, etc. Powdered carbon may also be introduced with the charge in order to reduce the waste of the carbon electrodes. In treating matte containing 22 per cent of copper, 58 per cent of nickel, 0.5 per cent of iron, and 28 per cent of sulphur, Mr. Browne adds to the charge in the electric furnace an equal weight of lime, and, if desired, powdered carbon to the amount of 5 per cent of the matte. (934,278, Sept. 14.)

Graphite.

Unctuous Graphite.—In converting petroleum coke, etc., into graphite in the electric furnace, the petroleum coke is embedded in an envelope of a mixture of sand and carbon. While the petroleum coke is converted into graphite, the sand and carbon are partly converted into petroleum. But the latter conversion is incomplete and on account of the fragile and non-coherent nature of the carborundum crystals, some of them are liable to become detached and contaminate the outer portions of the graphite. Since a mere trace of the exceedingly hard carborundum will completely destroy the value of graphite as a lubricant, there is a great loss of graphite. This is now avoided by Dr. E. G. Acheson by continuing the operation until the envelope of sand and carbon is completely changed into a coherent and firm mass of carborundum, which can be easily separated from the graphite. For this reason, Acheson continues the heating for 30 or 36 hours or even longer, as distinguished from the 12 or 18 hours in usual practice for graphitization. Further, while formerly a shallow envelope of sand and carbon was employed, Dr. Acheson now uses a deep or thick bed of this mixture; its thickness being at least one-half the diameter of the carbonaceous parts to be converted into graphite. (933,944, Sept. 14, 1909.)

Nitric Acid from Air.

Fixation of Atmospheric Nitrogen.—I. Moscicki, who has been working for a number of years on a method of fixation of atmospheric nitrogen by means of spark discharges, has now modified his apparatus somewhat along the principles of the Birkeland-Eyde process, but with quite different arrangements. This is shown in vertical and horizontal cross-sections in Fig. 4. Of the two electrodes, *a* *b*, the one *a* is of cylindrical form but rounded off at the lower end, while the other electrode *b* is formed by a body containing a larger number of passages communicating above and below with hollow cylinders. Both electrodes are arranged for being cooled by means of a liquid, for example, oil, water, etc., a tube *c* which is open at its lower end, extending into the electrode *a* nearly to the point thereof, while in the case of the electrode *b*, there is only a cooling jacket provided with an admission and a discharge pipe. The cooling of the electrode *a* is effected by the admission of the cooling liquid through the tube *c* and the discharge of the same through the pipe *d*. The two electrodes are mutually insulated by means of the sleeve *e*, which is made of good insulating material. The electric energy is supplied through conductors *f* and *g*. The surface of the electrode *b* situated

opposite the free end of the electrode *a* is flat and only slightly distant from the former. As shown, the electrode *b* extends entirely across the furnace chamber and forms its lower end wall. The middle portion of the electrode *b* is surrounded by a coil which is intended to produce a powerful magnetic field. The magnetic lines of force of this field are vertical to the flat surface of the electrode *b*.

The gases enter through the pipe *i*, pass the hollow space surrounded by the electrode *b* and force the flame against the surface of the electrode *b*, pass through the flame and go out of the apparatus through the passages in the electrode *b*. The apparatus is specially suitable for working under pressure. The effect of the magnetic field is to make the arc revolve so as to sweep over nearly the whole extent of the plate-shaped electrode. As the electric flame sweeps over the whole upper surface of the electrode *b*, the course from the place of action (that is to say, the flame) to the metallic cooling covered by the products obtained through reaction is exceedingly short, in consequence of which, as the gases are forced violently against the metallic electrode, this cooling of the entire body of the gases takes place momentarily or suddenly after the reaction, that is, after the gas has passed the electric arc or flame, and the quantity of gas serving for the cooling can be considerably reduced. These discharging passages are suitably

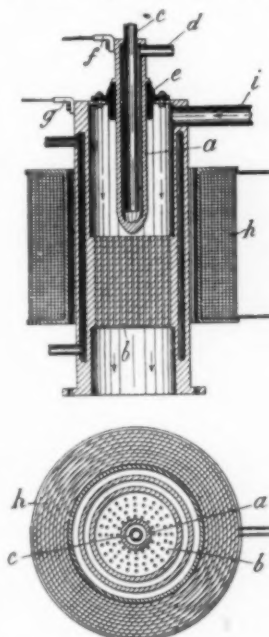


FIG. 4.—FIXATION OF ATMOSPHERIC NITROGEN.

dimensioned so that the cooling of the gases to 700° C., or the temperature at which the gases produced will not decompose, is possible. Assuming that all conditions and dimensions are suitable, only ¼ cubic meter of gas will be required per kw-hour flame energy (while it is claimed for the ordinary flame arrangement that such a large quantity of gas is needed for cooling as to require not less than 2.5 cubic meters per kw-hour). The electrodes are made of copper. (933,084, Sept. 7, 1909. Another patent of the same inventor is No. 930,212, of Aug. 3, 1909.)

Nitric Acid from Air.—The new process of the Badische Company was described in detail and illustrated in our June issue, page 245. We, therefore, notice here simply, without further discussion, the fundamental patent for this process, granted to Dr. O. Schönherr and J. Hessberger. Some of the claims are quite broad. For instance, the first one, relating to "the process of producing a long stable electric discharge which consists in stretching the discharge from one terminal alongside another by means of a current of fluid," or the 7th claim referring to "the process of maintaining a long electric arc which consists in maintaining an enveloping current of fluid as a shield against lateral escape." (930,238, Aug. 3, 1909.)

Sulphuric Acid.

Electrolytic Process for Oxidation of Sulphurous Acid.—A patent of G. C. de Briailles refers to a process of manufacture, concentration and simultaneous purification of sulphuric acid, in which the sulphuric acid is produced by direct oxidation of sulphurous acid by "nascent oxygen" obtained by an electrolytic decomposition of water. "The sulphurous acid enters by the positive electrode and is scrubbed in the water (which is decomposed under the action of the current) until the oxygen is released, which acts in a nascent condition." The hydrogen is separately collected. As shown in Fig. 5, the apparatus con-

sists of an external earthenware vessel *A*, capable of supporting a certain pressure. A second cylindrical vessel *B* of porous porcelain is inserted axially in the vessel *A*. A platinum wire *C* placed in the axis of the vessel *B* serves for connection to the positive pole. In the vessel *A*, a mixture in suitable proportions of granules of retort carbon or coke and antimonial lead, is packed all around the vessel *B*. An antimonial lead rod *D* passes through the mass of these granules and serves as connection to the negative pole. A tight-fitting earthenware lid or cover *E* hermetically closes the vessels *A* and *B*, with the aid of a mastic, which resists the action of concentrated sulphuric acid. The two rods *C* and *D* pass through tight joints.

A suitably proportioned mixture of liquefied sulphurous acid, supplied directly from the furnaces and compressed to the

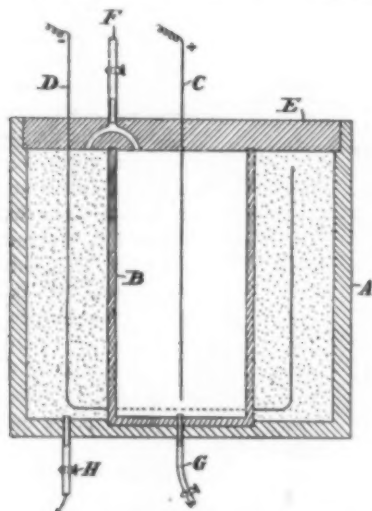


FIG. 5.—ELECTROLYTIC CELL FOR SULPHURIC ACID.

desired degree, and of sulphuric acid at 45° Baume—that is to say, having a sufficient quantity of water to give it the same density as the liquid sulphurous acid, is introduced into the two vessels *A* and *B*, by a pipe *F*, which passes through a hermetically closed joint in the cover or lid *E*. Of course, the pressure must be maintained at the necessary minimum. "The water thus introduced into the apparatus has for its object to insure the conductivity of the mixture necessary for the electrolysis, at the same time it is itself decomposed, furnishing at the anode the nascent oxygen, which oxidizes the sulphurous acid and converts it into sulphuric acid around the platinum wire *C*." At the same time, if the current is of a suitable intensity, very fine and pure sulphur is deposited in proximity to the negative electrode *D*, by the action of the sulphydric acid due to the reduction of a portion of the sulphurous acid by the nascent hydrogen. The size and especially the distance apart of the walls and vessels *A* and *B* must be small, and the current of sulphurous acid sufficiently rapid. A tube *G* for discharging the sulphuric acid connects with the lower part of the vessel *B*. In the vessel *A* around the carbon and antimonial-lead granules, and around the rod *D*, the solution of ordinary sulphuric acid mixed with the liquid sulphurous acid is renewed simultaneously with the latter.

At the end of a certain time, when the precipitated sulphur has accumulated in the vessel *A* and the vessel *B* is filled with concentrated sulphuric acid, the inflow of sulphurous acid at *F* is stopped, and the pressure is suspended, and the sulphurous acid which expands and vaporizes is collected in a gas generator. A part of the concentrated sulphuric acid is withdrawn at *G*, and at *H* the semi-liquid sulphur, while water which assists this latter operation is introduced at *F*. The sulphur is separated by decantation and then the vessel is set going again as before. Instead of sulphur other by-products may be obtained according to fluctuations of commercial requirements. Thus, by lowering the sulphurous and sulphuric acid contents

in the initial solution to be electrolyzed, the voltage may be lowered and the hydrogen will be released at the cathode without combining. (928,844, June 20, 1909.)

Manufacture of Sulphuric Acid.—While, besides its applications in medicine, radio-activity has so far been chiefly of scientific interest, Mr. W. Hallock wants to employ it to an intensely practical problem of chemical engineering, the change of SO_2 to SO_3 , without any catalytic agent and without elaborate apparatus. His process comprises "the oxidation of the sulphurous oxide by means of the ionization of one or more of the gases evolved by radium, uranium or other radio-active substance or by X-rays, cathode rays, Lenard rays or ultra-violet light, or other ionizing substance or agency." He has found that "a comparatively feeble agent serves to bring about the oxidation of sulphurous oxide if oxygen is present, and the ionizing influences serve to accomplish this result—that is, to put the atmosphere in such a condition as to precipitate the acid." (930,471, Aug. 10, 1909.)

Caustic Soda and Chlorine.

Iron Oxide Electrode.—In the plants using the Griesheim "elektron" diaphragm process for the electrolytic production of caustic soda and chlorine, iron oxide anodes have been employed for a few years. Their advantage over carbon anodes is that the chlorine gas produced will not be mixed with carbon dioxide. These iron oxide electrodes are made from molten Fe_2O_3 or molten Fe_3O_4 . When Fe_2O_3 is melted, oxygen escapes and Fe_3O_4 , together with a small proportion of FeO , are formed. The presence of this FeO is objectionable for two reasons; first, it causes cracking of the electrodes when cooling; second, the electrodes will not resist chlorine. It is, therefore, important in the manufacture of electrodes to eliminate the FeO . For this purpose H. Specketer adds to the molten mixture a small quantity of unmelted, finely pulverized Fe_2O_3 which unites with the FeO to form Fe_3O_4 , instead of Fe_2O_3 . He may also add Cr_2O_3 or Mn_2O_3 . The homogeneous crystallizing melt thus produced is poured into molds, closed at the bottom. The mass solidifies gradually from the outside so that a rigid layer is first formed on the exterior, which layer gradually increases in thickness toward the center of the mass. When such layer has reached the desired thickness, the remainder of the fluid contents of the mold is returned to the melting vessel to be used for a new charge. The mold is then opened and the electrode, which is closed at its lower end, is removed and allowed to cool slowly. (931,513, Aug. 17, 1909.)

Magnesia.

Magnesium.—At present magnesium is produced electrolytically from an electrolyte of fused magnesium chloride, with potassium chloride added as a flux, the separated magnesium being collected at the bottom of the vessel. It is only under certain conditions of temperature that such an electrolyte is lighter than the separated magnesium, and it is difficult to so manage the process that these temperature conditions are maintained so that a good separation of the magnesium results. G. O. Seward and F. von Kugelgen (Virginia Laboratory Company) accomplish the separation of the produced magnesium from an electrolyte, by using a heavier electrolyte, by the addition of one of the salts of the alkali earth metals. For instance, in the process above mentioned, they replace the potassium chloride partly by barium chloride, using, for instance, an electrolyte containing 5 parts of magnesium chloride, 5 parts of potassium chloride, 3.5 parts of barium chloride. In this electrolyte the produced magnesium rises readily to the top, where it is collected. (931,392, Aug. 17, 1909.)

Anti-Friction Alloy.—An anti-friction bearing alloy of lead, cadmium and magnesium is patented by E. A. Touceda. The magnesium is intended to harden and toughen both the lead and cadmium constituents. The alloy contains from one-tenth of 1 per cent to 5 per cent of magnesium, about 10 per cent of cadmium, and the remainder lead. (933,139, Sept. 7, 1909.)

Chromium and Other Refractory Metals.

Boron as Reducing Agent.—Mr. Frederick M. Becket, metallurgist of the Electro Metallurgical Company, proposes the use of borides of the alkali earth metals; for instance, calcium boride or carbon boride for the reduction of the oxide ores of chromium, tungsten, molybdenum, etc. Chromite may be directly reduced in this way. (930,028, Aug. 3, 1909.) In another patent by the same inventor, he proposes the use of boron-silicon alloys as reducing agent. Metallic chromium, for instance, may be produced in this way, directly from chromite. The operation is facilitated by the presence in the charge of a base capable of uniting with the oxide of boron produced. Most commercial chromites contain 8 to 15 per cent of alumina and a similar proportion of magnesia, and to the extent of their presence these serve the purpose of a basic flux. In case of ores free from basic constituents, or in case of the deficiency of such constituents, a suitable basic flux, as lime, is added as required. The slags are advantageously utilized for the production of borates, as, for example, the borates of the alkali metals, or they may be reduced by carbon in a separate operation. In the latter case, the boron constituent is recovered, usually in the form of an alloy with the other reducible constituents of the slag, as, for example, an alloy of boron with silicon, or with silicon and calcium, often in conjunction with a considerable proportion of the metal, as chromium, etc., originally reduced. In this form the boron may be repeatedly utilized for the reduction. (930,027, Aug. 3, 1909.)

Magnetic Concentration.

Roasting Furnace.—In obtaining a roast to be followed by magnetic separation, it is absolutely essential to prevent the ore particles from clinging together by reason of too much heat resulting in semi or partial fusion. As has been repeatedly noticed in this journal, Mr. Arthur R. Wilfley, of Denver, Col., avoids this difficulty by causing the ore to drop downwardly through a flue or chamber. At the bottom of this flue a water jacket or other cooling medium is arranged which the ore engages as it falls, thus suddenly cooling it before its particles are allowed to come in contact under such circumstances as to permit them to cling together. In a recent patent he refers to a difficulty due to the fact that the ignition of the impurities, such as sulphur, produces heat, and the ore has, therefore, a tendency to rise in temperature as it moves downward. There is, therefore, some danger that before reaching the bottom of the flue or chamber it may become heated to such a degree that there will be a strong tendency for the particles to cling together as they come in contact. This difficulty Mr. Wilfley now overcomes by the introduction of cold air at the bottom of the ore flue or chamber, which is carried upwardly in conduits, whereby it is separated from the ore and, therefore, does not interfere with the downward movement of the ore or with the draft of the furnace. As this air travels upwardly through the pipes, within the ore flue or chamber, its temperature rises, and by the time it reaches the top of the flue and escapes from the air pipes or conduits, it is exceedingly hot and comes in contact with the falling ore. By reason of this construction and arrangement the ore as it moves downward is subjected to the action or influence of the air within the pipes, which gradually becomes colder as the ore approaches the lower extremity of its flue or chamber. In this way the ore is partially cooled as it passes downwardly in the flue and the tendency to become overheated is neutralized. At the same time, by the introduction of the air through the pipes into the ore in the upper part of the flue, it becomes practicable to roast a heavy sulphide ore, without additional fuel, after the original firing of the furnace or the commencement of the roasting operation. (930,254, Aug. 3, 1909.)

Aluminium.

Aluminium Solder.—For soldering aluminium or for closing openings and cracks in aluminium articles, Z. Tamassy

patents a solder consisting of 130 grains of antimony, $\frac{1}{2}$ lb. of zinc spelter, $\frac{1}{2}$ lb. of pure tin and 44 grains of salicylic acid (powder). (931,523, Aug. 17, 1909.)

Aluminium Solder.—J. F. Guggenbuhl patents an aluminium solder which is claimed to be particularly adapted for securing together aluminium parts into solid articles such as have heretofore been made by crimping or clamping the parts together. The solder consists of 85 per cent zinc, 10.7 copper, and 4.3 aluminium. It is applied with the aid of a blowpipe. (933,433, Sept. 7, 1909.)

SYNOPSIS OF PERIODICAL LITERATURE**Iron and Steel.**

Influence of Temperature on Mechanical Properties.—Prof. M. Rudeloff, of the German Imperial Testing Laboratory, reported upon his carefully made experiments to the recent Congress of the Society for Testing Materials at Copenhagen. He heated the specimen by steam, naphthalene vapor or naphthylamine vapor in a specially constructed vapor bath attached to the testing machine. For the attainment of comparable results, uniform rapidity of applying the load is necessary. Temperatures were determined by thermo-electric couples, pressed against the sample itself. *Wrought iron* decreases in elongation up to 150° C., and increases in tensile strength up to 250°. The figures are:

C.°	Tensile Strength.		Elongation.
	Kg per sq. mm	Lbs. per sq. in.	Per cent
20	34.5	49,300	30.5
50	36.0	51,400	25.5
100	38.0	54,300	16.0
150	42.5	60,700	14.0
200	47.0	67,100	17.5
250	49.5	70,700	23.0
300	48.0	68,600	30.0
350	40.0	57,100	35.0
400	32.3	46,100	40.0

The results in general confirm those of Kunt Styffe, published in 1863. *Soft Bessemer steel* showed tensile strength decreasing to 50° C., then increasing to a maximum far above its ordinary strength, at about 250°, and thereafter a rapid decrease; the elastic limit, on the contrary, falls steadily with increase of temperature; the elongation before rupture falls rapidly and considerably as temperature rises to about 150°, then rapidly increases. This behavior of elongation and ultimate tensile strength explains the "blue-shortness" of steel first pointed out by Valtin in 1877, as noted in bending tests at various temperatures. *Soft open-hearth steel*, with low carbon (0.20 per cent), behaves similarly to the former, reaching its maximum strength at 200° to 300° and minimum elongation at 200°. Rudeloff's results are as follows:

C.°	Tensile Strength.		Elongation.
	Kg per sq. mm	Lbs. per sq. in.	Per cent
20	43.5	62,100	24.0
50	44.0	62,900	22.0
100	45.0	64,300	18.0
150	46.0	65,700	14.0
200	46.5	66,400	11.0
250	46.0	65,700	12.0
300	44.3	63,300	13.0
350	43.0	61,400	14.0
400	42.0	60,000	15.0
450	37.0	52,900	17.0
500	31.0	44,300	19.0
550	25.0	34,300	21.0
600	20.0	28,600	23.0

Cast iron retains its strength practically unimpaired to 400° C., but loses 30 per cent at 500° and 60 per cent at 600°. The specimen tested was a gray foundry iron containing 0.52 per

cent phosphorus. The hardness is nearly constant to 300° and then falls very rapidly. Malleabilized cast iron shows a slight increase of tensile strength to 275°, and then a rapid falling off; the elongation is practically constant to 400°-450° and then rises. A summary of the literature of the subject accompanies the article.

On a Uniform Nomenclature.—A committee of the International Society for Testing Materials made its second report on this subject at the recent International Congress of that society in Copenhagen. The committee is large to unwieldiness, and of the 26 members 6 are from Russia alone, while such an historically and commercially important iron-producing country as Sweden is not represented. Under such circumstances, a report of a high order, which might possibly have been acceptable to the scientific and commercial world, was not to have been expected—and has not been produced.

The report contains a glossary of terms, in English, German, French, Italian, Spanish, Swedish, Danish and Dutch. (The Hungarian members of the society have requested that Hungarian be added to the report as published.) The glossary is fairly complete. There is, further, a table of definitions in English which is intended to make precise the significance of the English terms. There is also an abridged statement of the present status of the metallography of iron and steel, with some suggested new terms.

In the field of definitions, *pig iron* is defined as "cast iron which has been cast into pigs direct from the blast furnace." This does not correspond to the facts; it should be rather "cast iron as produced by the reduction of iron ore or similar raw material." This latter definition would include melted pig iron which has not been cast into pigs, and also cast iron produced in an electric reduction furnace or in any other way—which materials are excluded from the committee's definition, but included in commercial usage. The use of the term "steel cast" as an adjective to apply to a steel casting which has been neither forged nor rolled is a phenomenon evolved, we fear, from the inner consciousness of the committee and really unknown to commerce or practice. "Steel" is carefully though somewhat awkwardly defined. We regret to see that such materials as electric (furnace) pig iron, electric (furnace) steel, open-hearth electric steel, Bessemer electric steel, and ferro-alloys are either unknown to the committee or else the terms used to designate them in commerce are considered beneath their consideration.

In the matter of the microscopical constituents (real and hypothetical) of iron and steel, the chief innovation is the proposition to use "metaral" as the equivalent of the longer term "microscopical constituents." It is pointed out that the longer term is inaccurate when applied to such "macroscopical" objects as the graphite in pig iron, and that "metaral" as applied to these would be the analogue of "mineral" as found in rocks. The analogy is faulty; minerals are chemical entities, and physical admixtures of minerals from rocks. While ferrite would be analogous to a mineral, pearlite would be analogous to a rock. It seems to us that the question is to distinguish by some term the ultimate chemical constituents of iron such as are given by a chemical analysis from the proximate physical constituents, such as can be separated or distinguished physically from each other. Would not the term "physical constituents," instead of "microscopical constituents," solve the difficulty? We commend it to the attention of metallographists and all interested in the subject.

Slag Enclosures in Steel.—Walter Rosenhain, of the (British) National Laboratory, read a paper at the Copenhagen Congress of the International Society for Testing Materials upon this important topic. He is convinced that sufficient attention has not been devoted to the harmful influence of these "physical constituents" of steel, and supports his thesis by photomicrographs of steels which have actually failed in use, all of which show the slag enclosures referred to. They are

best found by examining a section taken parallel to the direction of rolling or of extension, if the steel has been rolled or forged. By highly polishing, the enclosures in the steel appear either as "dove gray" sulphide of manganese or as minute black patches, which are either slag or the cavities from which the brittle particles of slag have been torn during the polishing process. These latter are either silicate of manganese or oxides or silicates of iron. In a rail which failed in service the slag enclosures were large and numerous. The manganese sulphide is best recognized by applying to the steel a sheet of photographic silver bromide paper moistened with dilute sulphuric acid, as suggested by Baumann, thus obtaining a "sulphur print."

The remedy for the manganese sulphide enclosures is evidently to keep the molten metal at rest for a sufficient time after the addition of manganese to allow the sulphide to rise into the slag. This takes considerable time, so much as to be difficult to apply in practice. The contamination with oxides is probably due to oxidation during teeming, while silicates can be readily formed by the incorporation of particles of silica from the refractory materials of the runners and molds; some may also be left in the steel as a sort of emulsion after the violent stirring together of slag and metal which occurs in the Bessemer process. Altogether, the quiet standing of the molten metal a considerable time before teeming, its protection from oxidation as far as possible during pouring, and the avoidance of loose or easily detached siliceous material in runners or molds, may go far to diminish the harmful effects which are undoubtedly caused by these slag enclosures.

Copper.

Copper Leaching.—*Metallurgie* of Aug. 8 contains a note by W. Borchers on a copper plant in Southern Tyrol, in which an attempt had been made to employ the old electrolytic process of Siemens, the first stage of which is leaching with ferric sulphate solution. In practice even this preliminary leaching process was a failure, so that the subsequent electrolytic precipitation of the copper was never attempted. The reason was that the ore contained the copper in form of the compound $\text{Cu}_2\text{S.FeS.FeS}_2$; this was roasted at such a high temperature that the copper oxide combined with other oxides and formed compounds like $\text{CuO.Fe}_2\text{O}_3$ and silicates. These are not amenable to leaching. Simple copper compounds can easily be leached; but when the copper compounds are combined with other sulphides or oxides, the attack of the ferric sulphate solution becomes a very slow reaction. An investigation of Dr. Thomas showed that roasting of the ore at a very low temperature (450° C. to 500° C.) yielded a product containing the copper partly as sulphate, partly as oxide, and partly as copper sulphide, free from FeS. The product of such a roasting process can easily be treated by leaching. For this reason, after the failure of the Siemens process, it was decided to work the copper ore simply for copper sulphate, for which there is a good market among the wine growers of Southern Tyrol. But as the copper deposit has since been found to be much larger than had been supposed at first, it is now proposed to work the ore either for copper matte or metallic copper. Professor Borchers thinks that for this ore concentration by the Elmore flotation process and subsequent smelting in the electric furnace would be particularly suitable. Experiments in this direction have been carried out at the Institute of Technology in Aachen and "the electric smelting experiments have gone so far that a decision will be possible within a short time." The local conditions for electric smelting are especially favorable, since a water-power of at least 3000 hp could be utilized, its development being possible with relatively low expense. If this decision should be reached, this would be the first commercial electric copper smelting plant.

Railroads and Metallurgy.—Bulletin 58 of the Institution of Mining and Metallurgy contains an advance copy of Dr. J. Douglas' paper on the influence of the railroads of the United States and Canada on the mineral industry.

A New Development in Continuous Annealing and Hardening Furnaces.

The Rockwell Furnace Company, 26 Cortlandt Street, New York, have recently improved their well-known type of in-

feed end. The gradual incline causes the material to feed forward, and by means of a hand-wheel the degree of pitch may be adjusted so as to regulate the progression of the material through the furnace, and consequently the time of heating.

The advantages of this method of automatic continuous heating are many. The material is charged in a hopper in bulk at the exhaust end of the furnace and fed automatically into the chamber, the material comes continually in contact with the newly heated surface of the chamber, which is revolving, thereby absorbing the heat from the lining as well as from the heated gases.

In a stationary furnace the heat from the sides and roof are not utilized, as the material remains in a fixed position; that farthest removed from the heat requires a much longer period to be brought to the desired temperature and the more exposed pieces are liable to overheating, while others insufficiently heated, and a much longer time required.

Tests of material being heated and hardened in the internally-fired rotary furnace at the rate of 2000 lb. per hour have failed to show the slightest variation. With a pyrometer to insure the proper temperature and the chamber tilted to feed at the proper speed the product must be absolutely uniform.

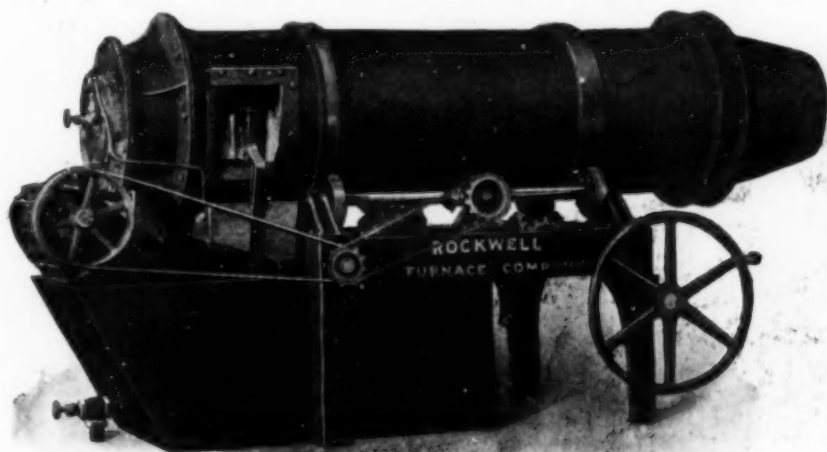


FIG. 1.—ADJUSTABLE AUTOMATIC ANNEALING AND HARDENING FURNACE.

ternally-fired rotary furnace, which gives a greater flexibility in range of work handled by it, and greatly adds to its durability. Gas or oil fuel may be used.

Heretofore these furnaces were built only with special lining brick which formed deep helical channels with separating spiral walls for feeding the material forward. This arrangement worked very well for light smooth pieces, such as lock washers, balls, etc., and is still spirally lined for this class of work, but was found to be unsuitable for long pieces, such as bolts, rivets, etc., and irregular shaped steel punchings, forgings, castings, etc., and other methods of feeding the material through the furnace were required.

In the present type of furnace, for smooth or round work, the rotating cylinder or drum is lined with a standard refractory hard brick, with a smooth internal surface. The furnace is mounted in such a manner that its axis may be tilted at an angle giving the revolving hearth an incline with the discharge end lower than the entrance or

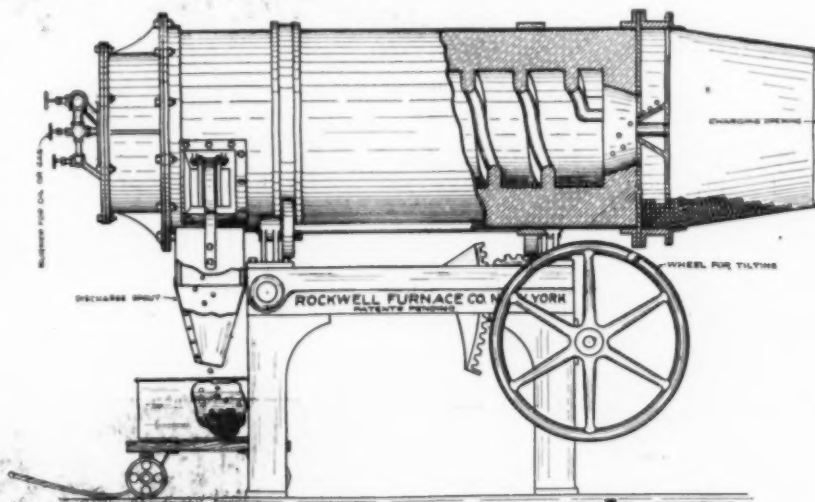


FIG. 3.—ADJUSTABLE INCLINED TYPE WITH HELICAL LINING.

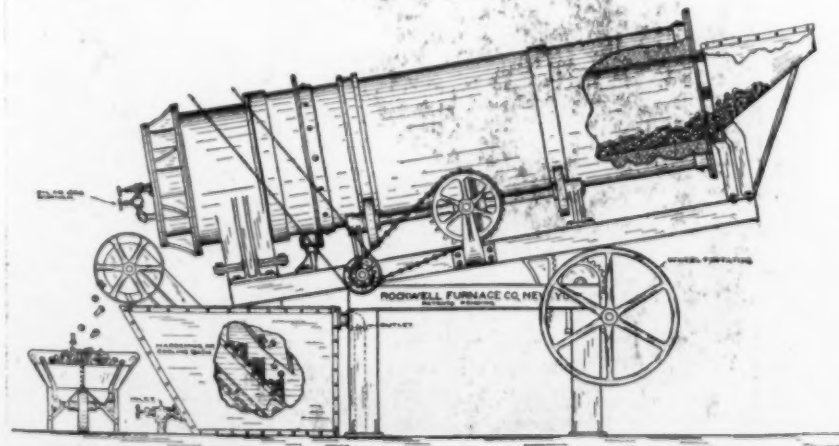


FIG. 2.—ADJUSTABLE INCLINED TYPE WITH PLAIN LINING.

In operation, the pieces are fed continuously into one end of the cylinder. The furnace is fired internally from the opposite end with the zone of highest temperature at the discharge end. The cylinder revolves slowly (1 to 4 r.p.m.) and owing to the slight inclination of the furnace, the pieces treated fall slightly forward at each revolution, gradually progressing toward the discharge end, where they enter a proper receptacle or bath upon reaching the desired temperature.

To prevent oxidation the end of the discharge spout may be carried beneath the level of the bath, thereby sealing it and excluding the air.

By this method, clogging or retardation of the work is avoided, as there are no

corners or pockets in which the pieces can lodge. Wear of the lining is reduced to a minimum and does not require renewal until the greater portion of the brick is worn away. In certain classes of work, such as balls, nuts and uniform shapes, the helical or worm type is used, and this furnace may be lined either way, as preferred, but where the smooth lining can be used the cost is less and a greater life is insured.

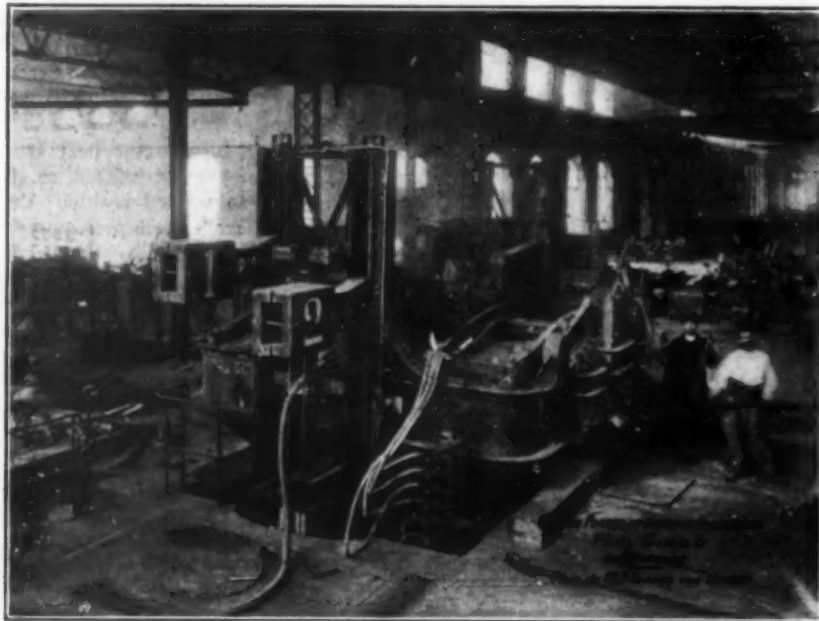


FIG. 1.—PLANT OF CIE. DES FORGES ET ACIERIES ELECTRIQUES, PAUL GIROD, UGINE, SAVOIE, FRANCE, 12½-TON FURNACE IN FRONT.

Oil or gas fuel may be used, and perfectly uniform results obtained, as the work treated is heated gradually with every portion of its surface exposed to the direct action of the hot gases and lining, and both temperature and time are maintained constant.

These furnaces are built to suit a wide range of requirements. In the standard sizes at present built for the trade, they are able to handle easily and satisfactorily up to 2000 lb. of stock per hour.

Girod Electric Steel Furnace.

We have repeatedly described the Girod electric steel furnace (see for instance our June issue, page 259, or July issue, page 323), and have also published a sketch of the new Girod steel works in Ugine, Savoie—the largest purely electric steel works in the world (our January issue, page 9). Castings, projectiles, tool steels, structural steel, etc., are there manufactured. For this reason, the accompanying three illustrations should be interesting to our readers. We are obliged for them to Messrs. C. W. Leavitt & Co., of New York, the American representatives of Mr. Girod.

Fig. 1 is an interior view of part of the Ugine works of Mr. Girod. A rear view of a 12½-ton Girod furnace is shown in the foreground.

A front view of the same 12½-ton furnace is shown in Fig. 2, while a 2½-ton Girod furnace is shown in Fig. 3.

Aside from these works, there are now 7 other European plants employing the Girod furnace.

Notes.

Steel Testing Machine.—The Landgraf-Turner alternating impact testing machine, made by Messrs. Queen & Company, of Philadelphia, is entering into general use for the testing of steels by impact. Queen & Company have just furnished one of these machines to the Bureau of Standards, Washington, D. C., and have also received an order from the Royal Italian Navy for one to go to Italy by the Italian cruiser now in New York Harbor.

Alundum as Refractory.—Alundum or artificial emery is made from bauxite in the electric furnace of the Norton Company at Niagara Falls. From a recent U. S. Geological Survey bulletin of W. C. Phalen on the production of abrasive materials in 1908 we take the following note on the use of alundum as a refractory, which is one of its more recent applications. Alundum melts at 2300° C. and has a very low coefficient of expansion, if it has any at all. It is, moreover, very inert chemically, and tests made in the basic open-hearth furnaces show that it is not appreciably affected by slags in these processes. The lining of a Deville furnace does not show deterioration after repeated burns at 1800° C. It remains to be proved just how much better alundum is than other standard refractories, as its cost will necessarily be quite high. It is believed, however, that for many special purposes it will prove of great value.

Carbon-Dioxide Recorder.—We have received from the Caldwell Company, 220 Broadway, New York, a pamphlet on the Westover CO₂ recorder. It is in principle similar to the hand analyzers of Hempel, Elliott, and Orsat, but exact mechanism takes the place of the human element. It is, therefore, "a machine and not an instrument." In the series of events, the taking of the sample gas, measuring of it, forcing it into contact with the potash solution, to the measuring of the residual



FIG. 2.—12½-TON GIROD ELECTRIC STEEL FURNACE.

part of the charge, all are carried out by tooth gear movements so connected and related that no event can take place out of its proper order or turn. These are operated by a small standard electric motor. The standard recorder is manufactured to make four records. Each record covers a period of 24 hours and the time between each analysis, about $1\frac{1}{8}$ minutes, thus making the records or analysis from each boiler about $5\frac{1}{2}$ minutes apart. The electric features of the Westover CO₂ recorder make it easy of adaptation to the Mailloux-Westover damper control, which operates by means of a combination of steam pressure and the rise and fall of the CO₂ gas within the furnace, insuring a step-by-step movement of the damper, adjusted at each step to the exact demands of the moment. The electric features also lend themselves to easy adaptation to the Mailloux-Westover boiler front CO₂ electric signals and to the making of signals

dry vacuum pumps, centrifugal pumps, centrifugal jet condensers, etc. The plant at Carteret, N. J., is being enlarged and improved. Among these improvements is a new power house which will be equipped with several different systems of condensers for exhibition purposes, as well as for supplying the electrical energy which will be used throughout the shop.

Monel Metal.—With respect to the full article of Mr. D. H. Browne on Monel Metal in our March issue, page 114, it is interesting to note that Monel metal sheets are now manufactured exclusively by the American Sheet & Tin Plate Company, of Pittsburgh. In a pamphlet, recently issued by this company, it is stated that it is "less expensive than nickel or German silver, since in the former the expense is largely in the difficulty of isolating it, and the latter is a manufactured instead of a natural alloy." Monel metal sheets are used for roofing (as

in the new Pennsylvania Railroad Terminal in New York) to supplant copper, and owing to their great strength and non-corrosive qualities, a much lighter sheet can be used and greater efficiency and service obtained at a lower initial cost. For this reason Monel metal is also specially suitable for smelter roofs, mine screens, chutes, tanks, kettles, and in general where non-corrosive qualities are important, as well as the toughness of the material to resist impact. Monel metal sheets are made by the American Sheet & Tin Plate Company in sizes up to 36 x 96 and all gauges. These sheets are rolled in the famous Vandergrift works, the largest sheet mill in the world.

High-Speed Tool-Steel Patent Decision.

—In our March issue we noticed the outcome of the famous patent suit of the Bethlehem Steel Co. versus the Niles-Bement-Pond Co. for infringement of the Taylor-White patents. This was decided in favor of the defendant and the two Taylor-White patents in question were found invalid by the Circuit Court of the United States for the District of New Jersey. On appeal, the United States Circuit Court of

Appeals for the third Circuit has now rendered the following opinion: "The opinion, filed in this case by the learned judge of the court below has so clearly stated the reasons upon which our own determination of this case is founded that further and independent discussion of them on our part is rendered unnecessary. Therefore, adopting the opinion of the court below as the opinion of this court, its decree is hereby affirmed."

Digest of U. S. Patents

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

ELECTRIC FURNACES (Continued).

628,782, July 11, 1899, James J. Faulkner, of Memphis, Tennessee.

The material to be smelted, for example a mixture of lime and carbon, is pressed from a hopper, by a fluted roller, between a pair of horizontal rolls, one plain and one grooved, being thereby formed into a series of pencils. Scrapers bear against the lower surfaces of the rolls. Beneath the hopper and rolls is the rectangular furnace chamber, of firebrick, having at one side a long horizontal carbon plate electrode, and in its opposite wall a row of openings, each receiving a carbon rod electrode. The carbon rods are forced longitudinally against the carbon plate by springs. The molded pencils of lime and carbon feed downward from the forming rolls to the electrodes, where they are smelted. The calcium carbide



FIG. 3.— $2\frac{1}{2}$ -TON GIROD ELECTRIC STEEL FURNACE.

or duplicate records at a near or great distance from the boiler plant.

The **Bristol Company**, of Waterbury, Conn., has opened a branch office in Pittsburgh, in the Frick Building Annex. They are now making a specialty of studying the application of Bristol's recording instruments in many different industries. For instance, they have specialized in recording instruments for blast furnaces, including recording pressure gages for hot blast, top gas and steam electric pyrometers for hot-blast temperatures, top-gas temperatures and general tests; electric time recorders for recording the movements of rotary top, skip hoist, large bell, small bell and gage rod, recording thermometers for Gayley dry-blast temperatures, condenser water temperatures, feed-water temperatures, etc.

The **Wheeler Condenser & Engineering Co.**, of Carteret, N. J., at the recent annual meeting of the stockholders, has elected Mr. J. J. Brown vice-president and general manager. Mr. Brown entered the condenser field some 15 years ago as Southwestern manager for the Henry R. Worthington Company and later became their general sales manager. After the formation of the International Steam Pump Company he became their general Western sales manager, with headquarters at Chicago, and resigned that position to take up his present work. The Wheeler Condenser & Engineering Company has recently introduced several important improvements in condensing apparatus, among which are the "dry tube surface condenser," which has shown some remarkable results in high vacuum work. The company has also in hand new and improved types of rotative

and unsmelted material pass downward from the smelting zone into a chute having a perforated bottom and screw conveyor, which separate the lumps from the fine material, these being separately discharged. A chimney leads from the smelting chamber.

629,008, July 18, 1899, Oscar Frölich, of Steglitz, Germany, assignor to Siemens & Halske Aktien-Gesellschaft, of Berlin, Germany.

Arc type. A furnace for producing, distilling and condensing metals, e.g., zinc. The furnace chamber is an iron crucible lined with carbon and serving as one electrode. The other electrode is a vertical depending carbon tube. To the upper end of this tube is fixed the condenser, which consists of a vertical cylindrical iron chamber containing a series of horizontal alternate rings and disks, serving as baffles. The gaseous and volatilized products from the arc smelting zone, at the lower end of the tube, pass upward into and through the condenser, the uncondensed gases escaping through a pipe at the top. In use, the charge-mixture is kept at such height, more or less embedding the condensing chamber, as to maintain the desired range of temperature therein; for example, in the case of zinc, a temperature decreasing from 900° C. at its bottom, to 500° C. or less at its top, the temperature in the zone of reduction being specified as 1800° C.

630,283, Aug. 1, 1899, Wilhelm Borchers, of Aix-la-Chapelle, Germany.

Resistance and arc types, especially for the production of calcium carbide. The furnace, or a series of furnaces, are surrounded by or pass vertically through a steam boiler. After the charge has been smelted, the resulting carbide, surrounded by a layer of unreduced material, is left for several hours in the furnace until the heat therein has been utilized for the generation of steam. A series of furnaces, arranged longitudinally in one large boiler, may be worked successively to produce steam continuously. When the furnaces are discharged, the unreduced portion of the charge is so cool that the carbon therein does not burn when exposed to air. The gases escaping from the smelting zone and charge are filtered by passing them through a body of "wood debris," shavings, granulated charcoal, or other vegetable or animal fibrous or porous material capable of retaining dust, and are then collected or fed to a gas engine. The furnace or furnaces have thin metal walls. In the resistance type, horizontal carbon rods pass through the sides, their opposed ends being joined by a resistor of solid or pulverized carbon. The arc type has vertical electrodes, one passing through a hinged base and the other depending within the chamber.

NEW BOOKS.

OSTWALD, WILHELM. The fundamental principles of chemistry. An introduction to all textbooks of chemistry. Authorized translation by Harry W. Morse. 349 pages. Price, \$2.25 net. New York: Longmans, Green & Company.

ROTH, W. A. Exercises in physical chemistry. Authorized translation by A. T. Cameron. 208 pages, illustrated. Cloth, \$2 net. New York: D. Van Nostrand Company.

MELLOR, JOS. W. Higher mathematics for students of chemistry and physics, with special reference to practical work. Third edition, enlarged. 662 pages. Cloth, \$4.50. New York: Longmans, Green & Company.

DEL MAR, W. A. Electric Power Conductors. 330 pages, illustrated. Cloth, \$2 net. New York: D. Van Nostrand Company.

WHITE, MARIAN. The fuels of the household; their origin, composition and uses. 95 pages. Cloth, 75 cents net. Boston: Whitcomb & Barrows.

FRANKLIN, W. SUDDARDS, AND ESKY, W. Dynamos and motors. 498 pages, illustrated. Cloth, \$4 net. New York: Macmillan Company.

DUFF, ALEXANDER WILMER. A textbook of physics. 698 pages, illustrated. Cloth, \$2.75 net. Philadelphia: P. Blakiston's Sons & Company.

BOOK REVIEWS.

Theoretische Chemie. By Prof. Dr. Walter Nernst. Sixth edition. 794 pages, 50 illustrations. Price, 20 marks (retail price in New York, \$6.50). Stuttgart: F. Enke.

It is a pleasure to note the appearance of the sixth edition of Nernst's excellent and well-known German treatise on theoretical chemistry. In comparison with former editions the work has again been revised and brought up to date. The extensive discussion of Nernst's new thermodynamical theorem is of especial interest.

Steam Power Plant Piping Systems, Their Design, Installation and Maintenance. By Mr. M. L. Morris, M.E. 506 pages, 309 illustrations. Price, \$5.00 net. New York: McGraw-Hill Book Company.

In this plentifully illustrated 500-page book, there is presented an abundance of matter of interest and value to the steam engineer and also to the chemical engineer who has to deal with the storage, heating, pumping and chemical treatment of liquids and gases.

As the author asserts, it is not a compilation of tables and data, and neither is it a mathematical treatise on the flow of gases, the coefficient of friction of fluids or of the properties of structural materials. The author gives a description of the numerous systems of arrangement of pipes, pumps, valves, gauges, drops, blow-offs, etc., to meet many varied conditions.

Numerous devices are described and illustrated, including condensers, heaters and purifiers; and in a manner such as to avoid giving the impression that the writer is attempting to advertise the product of any particular manufacturer. The text embodies a human interest element in the treatment of plant design so as to give some consideration of the comfort and efficiency of the employees who are to keep the plant in operation. The relation between the contractor, buyer, engineer and operator are dealt with, and the whole work gives the appearance of being based upon extensive practical experience of the writer.

Electro-Magnetic Ore Separation. By C. Godfrey Gunther. 193 pages, 81 illustrations. Price, \$3 net. New York: McGraw-Hill Book Company.

A patent was awarded in England on a process for separating iron minerals by means of a magnet in 1792 and magnetic separation of magnetite and apatite began in New York State in 1852. But rapid progress in magnetic concentration has been made in recent years. Aside from an excellent chapter in Ingalls' Canadian zinc report, no comprehensive review of the subject has been available in book form. For this reason Mr. Gunther's book is a welcome addition to metallurgical literature.

"The book has been prepared to gather into convenient form the published information on the magnetic separation of ores. The compilation has been supplemented by data from the writer's observations and an extensive correspondence with mill managers and manufacturers. It has been attempted to include only that which is of present commercial importance." It is essentially a practical book and its chief value lies in the description of commercial apparatus and processes, while with respect to the critical discussion of principles of magnetic separation the book should be strengthened in future editions.

There are eight chapters: Magnetism applied to ore dressing; principles of magnetic separation and preparation of the ore for treatment; separators for strongly magnetic materials; separators for feebly magnetic materials; the concentration of magnetite ores; the separation of pyrite and blende; the separation of siderite from blende; separation of miscellaneous ores and minerals.